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NORTH CAROLINA GEOLOGICAL SURVEY.

J. A. HOLMES, STATE GEOLOGIST.

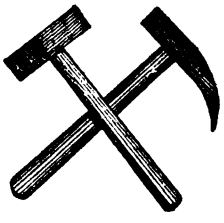
BULLETIN No. 9.

MONAZITE, AND MONAZITE DEPOSITS IN NORTH CAROLINA.

BY

HENRY B. C. NITZE,

ASSISTANT GEOLOGIST.



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PROSPECTING FOR AND MINING MONAZITE SAND.

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LETTER OF TRANSMITTAL.

RALEIGH, N. C., June 1st, 1895.

To His Excellency, HON. ELIAS CARR,

Governor of North Carolina.

SIR:—I have the honor to submit for publication as Bulletin 9 of the Geological Survey, a preliminary report on Monazite and Monazite Deposits in North Carolina, by Mr. Henry B. C. Nitze. The publication of this bulletin will serve as an answer to the many enquiries received by the Survey for information on this subject.

Yours obediently,

J. A. HOLMES,

State Geologist.

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MONAZITE.

By H. B. C. Nitze.

BRIEF DESCRIPTION OF THE MINERAL.

Monazite is essentially an anhydrous phosphate of the rare earths cerium, lanthanum, and didymium (Ce, La, Di), PO_4. It also contains, almost invariably, small percentages of thoria (ThO_2) and silicic acid (SiO_2), which may be present in combination as thorite or orangite ($ThSiO_4$), or the thoria may exist as the phosphate, either in combination with the cerium, etc., or as an isomorphous mixture. Other occasional accessory constituents are the yttrium and erbium earths, zirconia, alumina, magnesia, lime, iron oxides (Fe_2O_3 and FeO), manganous oxide, tin and lead oxides, fluorine, titanic acid, and water, usually in fractional percentages.

It is a subtranslucent to subtransparent mineral, light yellow, reddish yellow, brownish, or greenish in color, and has a resinous luster. It is brittle with conchoidal to uneven fracture. Its hardness is from 5 to 5.5, and its specific gravity from 4.9 to 5.3. It crystallizes in the monoclinic system.

HISTORICAL SKETCH AND NOMENCLATURE.

The following names have been applied to the mineral by independent discoverers and workers: Turnerite, monazite, mengite, edwardsite, eremite, cryptolite, monazitoid, phosphocerite, urdite, and kårarfveite. It was not long, however, before the identity of these newly described mineral species was recognized, and at the present time the general name in use is monazite.

The name "turnerite" was given in 1823 by A. Levy[1] in honor of the English chemist, E. H. Turner, in whose collection the first specimens were found. The locality of these was Dauphiny. They had been classed as sphene, on account of their color, accompani-

[1]The Annals of Philosophy, London, 1823, vol. 5, p. 241.

ment (adularia and lamellary crichtonite), and the locality; but Levy found their hardness to be less than that of sphene, and a good cleavage in one direction. He gives as the primary crystallographic form an oblique rhombic prism with differment dimensions from that of sphene. G. vom Rath[1] has also called attention to the fact that titanite (sphene) may be confounded with tunerite from general resemblance. In the fifth edition of his Mineralogy (American edition, Boston, 1844) Phillips says that monazite is occasionally known among mineralogists under the name of "pictite," which is one of the early names for titanite, with which it was doubtless confounded.

The date 1823, then, may be taken as that of the earliest recognition of a new mineral species which was later shown to be identical with monazite. Thus, in 1866, J. D. Dana[2] demonstrated the identity between turnerite and monazite by similarity of crystal form and physical properties. No chemical examination of turnerite had yet been made at that time. In 1870 this was substantiated by G. vom Rath,[3] and although he recognized the priority of Levy's name, turnerite, he did not feel justified in abandoning the name monazite, inasmuch as the latter belonged to a chemically as well as a crystallographically known mineral, while the composition of turnerite was not yet so well known. In 1873 Des Cloizeaux,[4] by the orientation of the optical axes, and Pisani,[4] by the chemical determination of P_2O_5 and Ce_2O_3, concluded that monazite and turnerite were the same species. In 1876 Trechmann[5] showed that the optical properties of turnerite and monazite were the same. In 1826 Menge discovered some crystals in the Ilmen mountains, near Miask, Siberia, which he held for a variety of zircon. Fiedler[6] gives the more exact locality of these specimens as being not in the Ilmen mountains proper, but in their southern extension, in the so-called Tscheremtchanka. The first scientific description of these was given by Breithaupt[7] in 1829. He gave it the name, "monazite" (monazit, monacite), from the Greek,

[1]Poggendorff, Annalen, 1864, vol. 122, p. 407.
[2]Am. Jour. Sci. vol. 42, 1866, p. 420.
[3]Poggendorff, Annalen, Erg.- Bd. 5, 1871: p. 413; Sitzungsber. Bayer. Akad. Wiss., 1870, vol. 2, p. 271.
[4]Zeitscher. Deutscher. geol. Gesell., Berlin, vol. 25, 1873, p. 568.
[5]Neues Jahrbuch, 1876, p. 593.
[6]Poggendorff, Annalen, 1832, vol. 25, p. 332.
[7]Schweigger-Seidel, Journal der Chemie u. Physik, 1829, vol. 55, part 3, p. 301

meaning "to be solitary." In 1831 H. J. Brooke[1], in describing specimens from Menge's locality in the Urals, gave the name mengite, in honor of the discoverer.

Prof. C. U. Shepard[2] in 1837 gave a description of "edwardsite," a new mineral from Norwich, Connecticut, which he named in honor of the governor of the State. Later in the year[3] he described another new mineral from Watertown, Connecticut, under the name of "eremite," after the Greek, meaning "solitude," but he did not then recognize its identity with edwardsite. Prof. J. D. Dana published in 1838 his crystallographic measurements of eremite, which agree with those of monazite.[4] In 1840 Gustav Rose[5] proved the identity, crystallographically and physically, of edwardsite and monazite. And in the second edition of his Mineralogy (1844) Shepard places both edwardsite and eremite under the head of monazite.

In 1842 Rose[6] gave a detailed description of the Russian monazite.

Woehler,[7] in 1846, discovered some small needle-like crystals invisibly included in the apatite of Arendal, Norway. They were of a pale-yellow color, specific gravity approximately 4.6, and, according to analysis, were composed of phosphate of cerium, but contained no thoria, and in this he distinguished the mineral from monazite, calling it "cryptolite," from the Greek, meaning "concealed." Although the forms of these crystals are different in appearance from that of ordinary monazite, Mallard,[8] in 1887, by careful goniometric measurements, established the identity of the two minerals.

Hermann,[9] in 1847, applied the name "monazitoid" to certain brown colored bent and broken crystals, of the specific gravity 5.28, from Lake Ilmen, near Miask, which contain less phosphoric acid (only 18.7) than monazite, besides some tantalic acid (3.75 to 6.27 per cent). Kokscharow[10] believed that monazitoid was simply impure

[1]Poggendorff, Annalen, 1831, vol. 23, p. 362; Philos. Mag. and Annals, vol. 10, p. 187.
[2]Am. Jour. Sci. (1), 1837, vol. 32, p. 162; Poggendorff, Annalen, 1838, vol. 43, p. 148.
[3]Am. Jour. Sci. (1), 1837, vol. 32, p. 341.
[4]Am. Jour. Sci. (1), vol. 33, 1838, p. 70.
[5]Poggendorff, Annalen, 1840, vol. 49, p. 223.
[6]Reise nach dem Ural und Altai, vol. 2, p. 87 and 482, Berlin, 1842.
[7]Poggendorff, Annalen, 1846, vol. 67, p. 424.
[8]Bull. Soc. Min., 1887, vol. 10, p. 236.
[9]Jour. prakt. Chemie, vol. 40, 1847, p. 21; Annuaire de Chemie, 1848, pp. 146.
[10]Materialien zur Mineralogie Russlands, vol. 4, 1862, pp. 7-34.

monazite, the tantalic acid having been derived from columbite and samarskite, with which the crystals are intergrown.

Blomstrand[1] analyzed specimens from probably the same locality as Hermann's monazitoid, but found no tantalic acid.

In 1850 Watts[2] described a new mineral occurring in the cobalt ore of Johannisberg, Sweden, which he showed to be a phosphate of cerium (including lanthanum and didymium). He proposed the name "phospho-cerite." Its physical and chemical characters identify it beyond doubt with monazite.

Forbes and Dahll,[3] in 1855, described a mineral occurring in the granite of Urda, near Nöterö, Norway, under the name of "urdite," which E. Zschau[4] determined to be monazite.

F. Radominski,[5] in 1874, found a mineral inclosed in albite at Kårarfvet, near Falun, Sweden, which resembled monazite, but on analysis was found to contain a notable quantity of fluorine (4.35 per cent), and for that reason he proposed to class it as a separate species under the name "kårarfveite." Blomstrand[6] made an analysis of specimens from the same locality, and found only 0.33 per cent. fluorine. He concluded that it was but an impure form of monazite.

CRYSTALLOGRAPHY.

MORPHOLOGICAL.

The primary form of monazite and its equivalents, turnerite, edwardsite, and mengite, was early stated to be the oblique rhombic prism of the monoclinic system. The crystallographic studies of the mineral by Koksharow, Des Cloizeaux, Websky, Dana, Vom Rath, and others have shown the occurrence of the following forms:

[1]Zeitschr. für Kryst., vol. 20, 1892, p. 367, Lunds Universitets Årskrift, 1888 (24).
[2]Quart. Jour. Chem. Soc. London, 1850, vol. 2, p. 131.
[3]Nyt Mag. Naturvidenskaberne, vol. 8, 1855, p. 227; Am. Jour. Sci., vol. 22, 1856, p. 262
[4]Allg. deutsche naturh. Zeitung, Dresden, 1857, p. 208; Am. Jour. Sci,, II, vol. 25, 1858 p. 410.
[5]Compt. Rend., 1874, vol. 78, p. 764.
[6]Zeitsch. für Kryst. vol. 19, 1891, p. 109; Geol. Föreningens Förhandl. Stockholm, 1889, vol. 2, p. 174.

Observed forms of monazite.

Pinacoids.	Prisms.	Hemi-domes.	Hemi-pyramids.
oP	∞P	$+ P\bar{\infty}$	$+ P$
$\infty P\bar{\infty}$	$\infty P\bar{2}$	$- P\bar{\infty}$	$- P$
$\infty P\grave{\infty}$	$\infty P\bar{3}$	$-7P\bar{\infty}$	$+\frac{1}{2}P$
	$\infty P\grave{2}$	$-\frac{3}{5}P\infty$	$-\frac{1}{2}P$
		$P\grave{\infty}$	$+ P\bar{2}$
		$2P\grave{\infty}$	$+2P\bar{2}$
		$\frac{1}{2}P\grave{\infty}$	$+3P\bar{3}$
			$+2P\grave{2}$
			$-2P\grave{2}$

Of these, the more common forms are the ortho- and clino-pinacoids and domes, the unit prism, and the unit pyramids. The basal pinacoid is rare, having been observed only on crystals from the Urals[1] and from Alexander County, N. C.[2]

Among the rarer forms are: $-\frac{3}{5}P\bar{\infty}$, found by Trechmann on turnerite from the Binnenthal, Switzerland; $-7P\bar{\infty}$ and $-\frac{1}{2}P$, found by Miers in Cornwall; and $\frac{1}{2}P\grave{\infty}$, on crystals from Nil St. Vincent, Belgium, and western Siberia.

The usual crystal habit is tabular, parallel to $\infty P\bar{\infty}$; also short columnar, and sometimes elongated parallel to ∞P. Cryptolite occurs always in very small crystals, elongated parallel to ∞P. The crystals are usually well developed and free from distortion. They vary in size from the microscopic needles of cryptolite, which have a thickness of .004 to .016 mm. (0.00015 to 0.00062 inch), to the abnormally large monazite crystals that have been found in Amelia County, Va., 5 inches in length. The more general variation lies between one twentieth and 1 inch. Irregular masses of monazite, devoid of crystal planes, as large as 15 to 20 pounds, have been found in Amelia County, Va., and in rounded masses up to 12¼ pounds at the Villeneuve mica mine in Ottawa County, Quebec.

Twins are not common. The twinning plane is parallel to $\infty P\bar{\infty}$; also to oP (Zirkel, Vol. I, p. 432.) Twins are sometimes cruciform.

[1]N. von Koksharow, Materialien zur Mineralogie Russlands, vol. 4, 1862, pp. 7-34.
[2]G. von Rath, Zeitschr. für Kryst., vol. 13, 1888, p. 596.

The axial ratio has been determined on specimens from different localities, as follows:

Axial ratios of monazite from various localities.

$\bar{a}$	$\bar{b}$	$\bar{c}$	β(oP∧∞P$\bar{\infty}$)	Localities.	Determined by—
			° ′		
0.9742	1	0.9227	103 46	Watertown, Conn. (eremite)	J. D. Dana.
0.9705	1	0.9221	103 46	Ural Mountains, Sanarka	Koksharow.
0.9658	1	0.9217	103 28	Laacher See (turnerite)	Vom Rath.
0.9609	1	0.9081	103 26½	Hiddenite mine, N. C	Do.
0.9693	1	0.9255	103 40	Milhollands Mill, N. C	E. S. Dana.
0.9735	1	0.9254	103 37	Schüttenhofen, Bohemia	Scharizer.
0.9718	1	0.9233	103 ·42	Nil St. Vincent	Franck.

Some of the principal angular measurements are:

Angular measurements of monazite.

∞P$\bar{\infty}$∧∞P			oP∧P$\bar{\infty}$			∞P$\bar{\infty}$∧oP			∞P$\bar{\infty}$∧P			∞P$\bar{\infty}$∧P$\bar{\infty}$			Localities.	Measured by—
°	′	″	°	′	″	°	′	″	°	′	″	°	′	″		
43	25	0				76	14	0				39	20	0	Watertown, Conn., (eremite).	J. D. Dana.
43	18	30	37	11	0	76	14	0	59	37	0	39	03	0	Ural Mountains, Sanarka.	Koksharow.
43	12	30	37	12	30	76	32	0	59	42	30	39	20	30	Laacher See (turnerite).	Vom Rath.
43	17	10	37	07	40	76	20	0	59	40	0	39	12	30	Milhollands Mill, N. C.	E. S. Dana.
43	25	0	37	03	0	76	23	0	59	36	0	39	20	0	Schüttenhofen, Bohemia.	Scharizer.

PHYSICAL CRYSTALLOGRAPHY.

The cleavage is most perfectly developed parallel to the basal pinacoid (oP.); it is also distinct as a rule parallel to ∞P$\bar{\infty}$; sometimes parallel to ∞P$\breve{\infty}$, imperfect; parallel to —P$\bar{\infty}$ (noticed by Vom Rath on turnerite from Laacher See[1]). Parting is sometimes developed parallel to oP and ∞P. It is brittle with a conchoidal to uneven fracture. The hardness is 5 to 5.5. The specific gravity varies from 4.64 to 5.3. The luster is resinous to waxy. The crystal faces are splendent in fresh, pure specimens; dull in weathered, impure specimens. The color is honey yellow, yellowish brown, amber brown, reddish brown, brown or greenish yellow. Derby[2] describes specimens of *lusterless, whitish* grains in muscovite granite of São Paulo, Brazil, which he proved to be cerium phosphate.

[1] Poggendorff, Annalen, 1871, Erg.-Bd. 5, p. 413; Sitzungsber. Bayer. Akad. Wiss. 1870, vol. 2, p. 271.
[2] Am. Jour. Sci. (3), vol. 37, 1889, pp. 109-114.

The monazitoid of Hermann is of a dark-brown color, due to impurities. In weathered specimens of impure monazite the surface is rough, dull, and sometimes covered with a light-brown earthy substance.

The purest specimens of monazite are transparent, becoming translucent and even totally opaque in the impure varieties.

It is frequently difficult to distinguish monazite, in fine grains, from certain other minerals by the uninitiated eye. Some varieties of yellowish-brown quartz are quite easily confounded with monazite; so also, at times, sphene, zircon, epidote, corundum, etc. For the benefit of the unscientific prospector it may be stated that the chief macroscopic distinctions are those of color, hardness, and specific gravity. The color is usually yellowish, inclined to reddish, brownish, or more rarely greenish tints. The fresh unaltered grains are transparent or translucent. The larger crystals are frequently dull in luster and opaque.

The hardness is from 5 to 5.5, between that of apatite and orthoclase (feldspar). Thus it can be scratched by a fragment of ordinary feldspar, (hardness 6) or quartz (hardness 7). The hardness of sphene is 5 to 5.5, of zircon 7.5, of epidote 6 to 7, of corundum 9. The specific gravity of monazite is 4.64 to 5.3; that of quartz is only 2.6, of sphene 3.5, of zircon 4.7, of epidote 3.25 to 3.5, of corundum 3.95 to 4.10.

OPTICAL CRYSTALLOGRAPHY.

Thin sections, by transmitted light, are colorless to yellowish. Pleochroism is generally scarcely noticeable. Absorption $\mathfrak{b} > \mathfrak{c} = \mathfrak{a}$. The plane of the optic axes is perpendicular to the plane of symmetry $\infty P\breve{\infty}$. The positive acute bisectrix lies in the obtuse angle β; hence sections parallel to oP show the full interference figure.

Optical measurements of monazite.

$b=\mathfrak{b}$	° ′	Localities.	Measured by—
$c \wedge c$	=1 04	(Turnerite) Tavetsch, Switzerland	Trechmann.
	=3 00	Arendal, Norway	Wülfing.
	=3 46	Norwich, Connecticut	Des Cloizeaux.
	=5 54	Schüttenhofen, Bohemia	Scharizer.

The opitcal angle is small; various measurements give:

Optical measurements of monazite.

2 E(red)	2 E(yellow).	2 E(violet).	2V (red).	2 V (yellow).	Dispersion.	Localities, etc.
° ′	° ′	° ′	° ′	° ′		
29 04	.....	28 48	.....	.....	$\rho > v$	Norwich, Conn., Des Cloizeaux.
31 08½	.....	31 43½	.....	.....	$\rho < v$	Sibera, Des Cloizeaux.
25 22	24 56	.....	.....	12 44	$\rho > v$	Schüttenhofen, Bohemia, Scharizer.
29 07	28 25	.....	14 50	14 29	.....	Pisek, Bohemia, Vrba.
34 12	.....	.....	.....	.....	$\rho < v$	Turnerite, Tavetsch, Trechmann.

The dispersion is weak and horizontal. The single refraction is high; double refraction considerable.

Optical measurements.

a	β	γ	$\gamma - a$	$\gamma - \beta$	$\beta - a$	Localities, etc.
1.9285	1.9465	.....	.....	.....	.....	Schüttenhofen, Bohemia, Scharizer.
1.7957	1.7965	1.8411	0.0454	0.0446	0.0008	Arendal, Norway, E. Wülfing.

CHEMICAL COMPOSITION.

COMPOSITION AND ANALYSES.

The earlier discoverers had very little knowledge of the true chemical composition of monazite. Breithaupt,[1] in 1829, concluded from the high specific gravity of the Siberian monazite that it was a metallic oxide or acid in combination with some of the earths. Shepard[2] stated in 1835 that monazite was inferred to consist of the oxide of uranium with some one or more of the earths (according to blowpipe tests of Breithaupt). At the same time turnerite, according to blowpipe experiments of Mr. Children, was supposed to contain chiefly Al_2O_3, CaO, MgO, and a little iron, with traces of SiO_2. In 1837 Shepard published an analysis of his edwardsite (see table, anal. No. 29, p. 19), in which he first pointed out the existence of cerium. He deduced the relationship P_2O_5: CeO=1: 1½, making

[1]Schweigger—Seidel, vol. 55, 1829.
[2]Treatise on Mineralogy, 1st edition; vol. 2, 1835.

the mineral a basic sesqui-phosphate of cerium protoxide. He also found 7.77 per cent ZrO_2, but it is doubtful whether this is an original constituent; more probably it may be referred to the presence of the mineral zircon as an impurity in the sample, which is an almost constant accompaniment of monazite. He found further, Al_2O_3, SiO_2, FeO, MgO, and a trace of glucina.

Kersten,[1] in 1839, analyzed the specimens from the Ural Mountains, previously determined by Breithaupt to be a combination of uranium oxide with some of the earths, but found no trace of uranium. He did find it to be essentially a phosphate of cerium and lanthanum oxides, and was the first to show the presence of La_2O_3, ThO_2, SnO_2, MnO, CaO, and traces of TiO_2, and K_2O. (See table, anal. No. 20, p. 18.)

In 1846 Woehler[2] published an analysis of cryptolite from Arendal, Norway, determining it to be a phosphate of cerium oxide. (See table, anal. No. 21, p. 18.) He could find neither ZrO_2 nor ThO_2, from which he concluded that the absence of ThO_2 distinguished cryptolite from monazite and edwardsite.

In 1847 Hermann[3] came to the conclusion that monazite was the neutral phosphate of cerium, in which a large part of the cerium was replaced by lanthanum and a small part by CaO, MgO, and MnO in the varieties of lighter specific gravity, while the heavier varieties (sp. gr. 5.281) contained less P_2O_5, and a large part of the stannic acid was replaced by tantalic acid (Ta_2O_5). (See table, anal. No. 17, p. 18.) This variety he called monazitoid, which occurs at Lake Ilmen, near Miask, Siberia. It is of a dark-brown color as distinguished from the lighter color of monazite. At first Hermann denied the presence of thoria in monazite and monazitoid, but later he found as high as 32.44 per cent ThO_2 in a specimen[5]. (See table, anal. No. 19, p. 18.) Monazite and monazitoid, he says, have the same form, and are therefore heteromeric, having different composition. Like all heteromeric minerals they show a tendency to mix, and thus give a series with slight difference in specific gravity. Koksharow[4] believed that monazitoid was simply an impure variety of monazite,

[1]Poggendorff, Annalen, vol. 47, 1839, p. 385.
[2]Poggendorff, Annalen, vol. 67, 1846, p. 424.
[3]Jour. prakt. Chemie, vol. 40, 1847, p. 21.
[4]Materialien zur Mineralogie Russlands, vol. 4, 1892, pp. 7-34.
[5]It is highly probable that the greater part of this was lanthanum.

where the tantalic acid was derived from columbite and samarskite, in which the crystals of monazitoid were intergrown, and this appears most probable. Blomstrand[1], in his analysis of specimens from the Ilmen Mountains (same locality as Hermann's monazitoid), found 16.64 per cent ThO_2, but no tantalic acid. (See table, anal. No. 15, p. 18.)

In 1850 Watts[2] published an analysis of his phosphocerite, which he determined to be a phosphate of cerium protoxide, including lanthanum and didymium.

Websky,[3] in 1865, in making blowpipe tests on monazite from the Riesengebirge, found cerium, phosphoric acid, and titanic iron; the latter, however, must have been an impurity in the powder, probably from the ilmenite, which is mentioned as occurring as an associated mineral in this locality.

Radominsky's variety of monazite, kårarfveite, from Sweden, was found by him to contain 4.33 per cent fluorine[4]. (See table, anal. No. 16, p. 18.) Blomstrand's analysis of a specimen from the same locality showed only 0.33 per cent fluorine. (See table, anal. No. 11, p. 17,) and he concluded that the so-called kårarfveite was simply an impure variety of monazite.

Scharizer[5] first pointed out, in 1887, the presence of an element of the erbium group in the monazite from Schüttenhofen, Bohemia. His determination was made on a thin section by means of a spectroscopic attachment to the microscope.

Genth,[6] in 1889, published an analysis of monazite from the Villeneuve mica mine in Canada, in which he determined 4.76 per cent of $(Y, Er)_2 O_3$. (See table, analysis No. 37, p 20.)

Blomstrand,[7] in 1889, also showed the presence of yttrium in the monazite from southern Norway; and he first pointed out here the presence of lead oxide.

Below is given a table containing a number of analyses of monazite from various localities, with references:

[1]Zeitschr. für Kryst., vol. 20, 1892, p. 367.
[2]Quart. Jour. Chem. Soc. London, vol. 2, 1850, p. 131.
[3]Zeitschr. Deutsch geol. Gesell., Berlin, vol. 17, 1865, p. 567.
[4]Compte Rendu, vol. 78, 1874, p 764.
[5]Zeitschr. für Kryst, vol. 12, 1887, p. 255.
[6]Am. Jour. Sci., vol. 38, 1889, p. 203; Zeitschr. für Kryst., vol. 19, 1891, p. 88.
[7]Zeitschr. für Kryst., vol. 15, 1889, p. 99; Geol. Föreningens, Förhandl., Stockholm. vol. 9, 1887, p. 160.

Analyses of monazite from various localities.

[Per cent.]

	1	2	3	4	5	6	7	8	9	10	11	12
P_2O_5	28.62	29.41	27.07	26.37	28.27	27.99	27.55	28.94	23.85	27.28	25.56	26.59
Ce_2O_3	32.52	36.63	25.82	31.23	28.06	30.98	29.20	30.58	27.73	30.46	37.92	29.62
La_2O_3	29.41	26.78	30.62	24.51	29.60	25.88	26.26	29.21	21.96	24.37	20.76	26.43
Di_2O_3												
Y_2O_3	2.04	1.81	2.03	1.83	1.82	2.76	3.82	.78	2.86	1.58	.83	2.54
ThO_2	4.54	3.81	9.60	9.20	9.34	9.03	9.57	7.14	9.05	11.57	8.31	10.39
SiO_2	1.51	.93	1.85	2.10	1.65	1.58	1.86	1.32	5.95	2.02	2.48	2.16
Al_2O_3	.22	.12	.15		.16			.18			.41	
Fe_2O_3	.36	.33	1.01	1.97	.66	1.25	1.13	.42	4.63			
FeO										1.10	.36	.75
MnO			.08	.28						.24		
CaO	.84	.34	.91	.93	.53	.55	.69	1.19	4.83	1.05	1.17	.88
MgO			.03	.16								
ZrO_2									.66			
SnO_2	.22	.09		.21						.08	.13	
PbO			.58					.33		.26	.34	.31
F											.33	
Ta_2O_5												
TiO_2												
H_2O	.27	.18	.35	1.53	.21	.20	.52	.09	1.61	.38	1.65	.52

1 to 10 inclusive. From pegmatite veins of southern Norway, by C. W. Blomstrand, Geol. Föreningens Förhandl., Stockholm, 1887, vol. 9, p 160. Zeitschr. für Kryst., vol. 15, 1889, p. 99.

11. From Kårarfvet, Sweden, by C. W. Blomstrand.

12. From Hölma, Sweden, by C. W. Blomstrand, Geol. Föreningens Förhandl., Stockholm, 1889, vol. 11, p. 171; Zeitschr. für Kryst., 1891, vol. 19, p. 109.

Analyses of monazite from various localities.

[Per cent.]

	13	14	15	16	17	18	19	20	21
P_2O_5	27.32	25.09	19.13	27.38	17.94	28.05	28.15	28.50	27.37
Ce_2O_3	31.31	34.90	22.88	.....	*a*49.35	*a*37.36	35.85	26.00	.....
La_2O_3	31.86	17.60	14.69	67.40	21.30	27.41		23.40	73.70
Di_2O_3	.....	.....	.....	.....	.....	.....	.....	.....	.....
Y_2O_3	.52	.43	1.71	.....	.....	.....	.....	.....	.....
ThO_2	5.55	17.82	16.64	.....	.....	.....	32.45	17.95	.....
SiO_2	1.37	2.90	9.67	.....	.....	.....	.....	.....	.....
Al_2O_3	.13	.....	2.90	.....	.....	.....	.....	.....	.....
Fe_2O_3	.26	.43	.....	.32	Tr.	.....	.....	.....	.....
FeO	.....	.....	3.56	.....	.....	.....	.....	.....	1.51
MnO	.....	.....	4.89	.....	.....	.....	.....	1.86	.....
CaO	.55	.36	1.25	1.24	1.50	1.46	1.55	1.68	.....
MgO	.....	.....	.40	Tr.	Tr.	.80	.....	.....	.....
ZrO_2	.....	.....	.....	.....	.....	.....	.....	.....	.....
SnO_2	.95	.43	.40	.....	.....	1.75	Tr.	2.10	.....
PbO	.....	.....	.....	.....	.....	.....	.....	.....	.....
F	.....	.....	.....	4.35	.....	.....	.....	.....	.....
Ta_2O_5	.....	.....	.....	.....	6.27	.....	.....	.....	.....
TiO_2	.....	.....	.....	.....	.....	.....	.....	*c*Tr.	.....
H_2O	.41	.56	.71	Some.	1.36	.....	1.50	.....	.....

a=CeO. c=TiO_2+K_2O.

13 to 15, inclusive. From Ilmen Mountains, by C. W. Blomstrand, Lunds Universitets Årskrift, 1888, vol. 24. Zeitschr. für Kryst., 1862, vol. 20, p. 367.
16. From Kararfvet, Sweden, by F Radominski, Compte. Rendu, 1874, vol. 78, p. 764.
17. Monazitoid from Lake Ilmen, Miask, by R. Hermann, Jour. prakt. Chemie, 1847, vol. 40, p. 21.
18. From Ilmen Mountains, Siberia, by R. Hermann, Kok., Materialien zur Mineralog. Russ., vol. 4, 1862. Rammelsberg's Handbuch d. min. Chemie, 2d ed., 1875, p. 305.
19. Rammelsberg's Handbuch d. min. Chemie, 2d ed., 1875, p. 305.
20. From Ilmen Mountains, near Miask, by C. Kersten, Poggendorff, Annalen, vol. 47, 1839, p. 385.
21. Crypolite from Arendal, Norway, by F. Woehler, Poggendorff, Annalen, 1846, vol. 67, p. 424.

Analyses of monazite from various localities.

[Per cent.]

	22	23	24	25	26	27	28	29
P_2O_5	28.78	29.66	28.40	25.09	24.61	29.10	28.70	26.66
Ce_2O_3	27.73	67.38	59.1	36.64	68.08	*a* 46.14	31.30	*a* 56.53
La_2O_3	39.24		8.9	30.21		24.5	39.9	
Di_2O_3								
Y_2O_3								
ThO_2				1.23				
SiO_2	1.60			3.21				3.33
Al_2O_3				3.11				4.44
Fe_2O_3	1.30	*b* 2.95						Tr.
FeO								
MnO				Tr.				
CaO	.90							
MgO				Tr.				Tr.
ZrO_2								7.77
SnO_2								
PbO								
F								
Ta_2O_5								
TiO_2								
H_2O								

a=CeO. b=Fe_3O_4.

22. Monazite from Arendal, by C. F. Rammelsberg, Zeitschr. Deutsch. geol. Gesell., Berlin, 1877, vol. 29, p. 79; Zeitschr. für Kryst., 1879, vol. 3, p. 101.
23. From Johannisberg, Sweden, by H. Watts, Quart. Jour. Chem. Soc. London, 1850, vol. 2, p. 131.
24. Turnerite from Luzerne, by F. Pisani, Zeitschr. für Kryst., 1877, vol. 1, p. 405.
25 to 26, inclusive. From county of Gough, New South Wales, by A. Liversidge, Zeitschr. für Kryst., 1884, vol. 8, p. 87.
27. From Antioquia, New Grandada, by Damour, Ann. Chem. Phys. (3), vol. 51, p. 445.
28. From Caravellas, Brizil, by H. Gorceix, Zeitschr. für Kryst., 1887, vol. 12, p. 643.
29. Edwardsite from Norwich, Conn., by C. U. Shepard, Am. Jour. Sci., 1837, vol. 32, p. 162; Poggendorff, Annalen, 1838, vol. 43, p. 148.

Analyses of monazite from various localities.

[Per cent.]

	30	31	32	33	34	35	36	37
P_2O_5	28.18	29.28	26.12	29.32	26.05		26.95	26.86
Ce_2O_3	33.54	31.38	29.89	37.26				24.80
La_2O_3	28.33	30.88	26.66	31.60	73.82		64.45	26.41
Di_2O_3								
Y_2O_3								*d* 4.76
ThO_2	8.25	6.49	14.23	1.48		18.6		12.60
SiO_2	1.67	1.40	2.85	.32		2.7	5.85	.91
Al_2O_3								
Fe_2O_3								1.07
FeO								
MnO								
CaO								1.54
MgO								.04
ZrO_2								
SnO_2								
PbO								
F								
Ta_2O_5								
TiO_2								
H_2O	.87	.20	.67	.17	.45		.91	.78

$d = Y_2O_3 + Er_2O_3$.

30. From Portland, Conn., by S. L. Penfield, Am. Jour. Sci., vol. 24, 1882, p. 250; Zeitschr. für Kryst., vol. 7, 1883, p. 366.
31. From Burke County, N. C., by S. L. Penfield, Am. Jour. Sci., vol. 24, 1882, p. 250; Zeitschr. für Kryst., vol. 7, 1883, p. 366.
32. From Amelia County, Va., by S. L. Penfield, Am. Jour. Sci., vol. 24, 1882, p. 250; Zeitschr. für Kryst., vol. 7, 1883, p. 366.
33. From Alexander County, N. C., by Penfield & Sperry, Am. Jour. Sci., vol. 36, 1888, p. 322; Zeitschr. für Kryst., vol. 17, 1890, p. 407.
34. From Amelia County, Va., by G. A. König, Proc. Acad. Nat. Sci. Phila., 1882, p. 15; Zeitschr. für Kryst., vol. 7, 1883, p. 423.
35. From Amelia County, Va., by F. P. Dunnington, Am. Jour. Sci., vol. 24, 1882, p. 153; Zeitschr. für Kryst., vol. 7, 1883, p. 423.
36. From Ottawa County, Quebec, by G. C. Hoffman, Am. Jour. Sci., vol. 34, 1887, p. 73; Zeitschr. für Kryst., vol. 15, 1889, p. 127.
37. From Ottawa County, Quebec, by F. A. Genth, Am. Jour. Sci., vol. 38, 1889, p. 203; Zeitschr. für Kryst., vol. 19, 1891, p. 88.

Below are given the thoria contents of a number of samples from North Carolina, which were analyzed for the writer by Dr. Charles Baskerville, assistant chemist of the North Carolina geological survey. These analyses are not made on the pure mineral, but on the commercial monazite sand, which contains up to about 67 per cent. monazite, the remainder being quartz, garnet, zircon, and other accessory minerals.

Thoria contents of North Carolina monazite sand.

[Per cent.]

	1	2	3	4	5	6	7	8	9
ThO_2	0.175	0.225	2.15	2.25	0.40	6.54	0.125	0.29	2.48

	10	11	12	13	14	15	16	17	18
ThO_2	0.26	1.27	6.30	5.19	5.87	6.26	1.75	1.93	3.40

1. Bennett's Mill, Silver Creek, Burke County.
2. Northeast side Brindle Ridge, Burke County.
3. White Bank gold mine, Burke County.
4. Hall's Creek, at Morganton road crossing, Burke County.
5. Bailey's Creek, 3 miles southwest of Glen Alpine Station, Burke County.
6. Linebacher place, Silver Creek, Burke County.
7. Mac'Lewrath place, Silver Creek, Burke County.
8. East fork of Satterfield Creek, Burke County.
9. Mac Lewrath Branch, McDowell County.
10. Bracket town, South Muddy Creek, McDowell County.
11. Long Branch, McDowell County.
12. Alexander Branch, McDowell County.
13. Daniel Peeler's farm near Bellwood, Cleveland County.
14. Proctor's farm, near Bellwood, Cleveland County.
15. Wade McCurd's farm, Carpenter's Knob, Cleveland County.
16. Tailings from No. 15.
17. Henrietta, Rutherford County.
18. Fallston, Cleveland County.

METHOD OF ANALYSIS OF MONAZITE SAND.

The method of analysis employed by Dr. Baskerville is given below in his own words[1]. He claims only "approximate results, and absolute accuracy cannot be vouched for." It is substantially the same as Prof. S. L. Penfield's method[2] with a few modifications.

The pulverized sand, 2 grams, is weighed into a small flask holding about 100 c. c.; 10 c. c. H_2SO_4 (1:1) are added, and the whole cooked on a sand bath with frequent agitation, until the

[1]From a letter to the writer, March, 1895.
[2]Am. Jour. Sci. (3), vol. 24, 1882, p. 238.

acid becomes concentrated and fumes arise. A small funnel is used in the neck of the flask to prevent loss by spitting and bubbling. It is allowed to cool, and if not completely decomposed, a fresh amount of H_2SO_4 is added, and the previous operation repeated. Add a little water, keeping the temperature down as well as possible. The insoluble silicates are removed by filtering and washing with cold water. The clear filtrate is diluted to 400 or 500 c. c., and an excess of oxalic acid added, whereby the oxalates of the cerium metals and thorium are precipitated. This is done in the hot solution, allowing the same to boil a few moments after adding the oxalic acid. It is then allowed to remain in the cold for twelve hours, when it is filtered and washed with cold water.

The precipitated oxalates are ignited by heating slightly above faint redness. After all the carbon is burned off, the contents of the crucible are turned into a platinum or porcelain dish, washing the crucible with H_2SO_4 (1 :1). On heating, the oxides are usually dissolved completely; the excess of H_2SO_4 is gotten rid of by gentle heat. To accomplish this, the disk is placed on a triangle inside of an iron dish to which the lamp flame is applied. The sulphates, which are almost invariably colored red, yellow or orange, are dissolved in water. The whole mass is usually completely soluble in about 15 c. c. H_2O, but on further dilution a precipitate is formed. The solution is made up to 200 or 300 c. c., i. e., sufficient water is added to hold all the thorium sulphate in solution; it is then boiled and filtered. If the filtrate is acid, it is neutralized with NH_4OH, and the thorium is precipitated out by means of $Na_2S_2O_3$. The filtered precipitate is burned to ThO_2 and weighed as such in a platinum crucible.

CHEMICAL AND BLOWPIPE REACTIONS.

Monazite is with difficulty and incompletely soluble in hydrochloric acid. It is attacked completely by sulphuric acid, and by potassium acid sulphate. It is infusible before the blowpipe flame, turning gray. When moistend with H_2SO_4 it colors the flame bluish green (phosphorus reaction). The borax and salt of phosphorus beads are yellowish when hot, and colorless on cooling;

the saturated borax bead becomes enamel white on flaming. Fused with soda, the mass treated with water and filtered, the residue dissolved in a little HCl, the solution gives with oxalic acid a precipitate, which on ignition becomes brick red (cerium oxide). With soda on charcoal a little tin is sometimes obtained.

MICHRO-CHEMICAL REACTIONS.[1]

For cerium.—The dilute solutions of cerium sulphate or chloride give, with oxalic acid or ammonium oxalate, a precipitate, which is at first flocculent but soon becomes crystalline, being composed of fine, doubly terminated, often forked and serrated prisms; in more concentrated solutions these form themselves into radial groups. The little crystals have an oblique extinction and a high double refraction. In hot, very dilute solutions thin rhomboidal plates are precipitated, whose acute angle is about 86°; they have a tendency to form rectangular intergrowths, and appear to be monoclinic.

For phosphorus.—Phosphoric acid is precipitated in a solution of the sulphate by the addition of ammonium molybdate, which on drying gives little crystals resembling rhombic dodecahedrons, yellow in reflected and greenish in transmitted light.

Derby[2] has found that these micro-chemical tests are the best means of identifying monazite.

SPECTROSCOPIC TESTS.

Scharizer[3] tested the absorption spectrum of a basal cleavage plate of the Shüttenhofen monazite by replacing the ocular of the microscope with a spectroscope *à vision directe.* The illumination was obtained by the reflection of direct sunlight from a concave mirror. The spectrum showed a broad absorption band in the yellow between the Fraunhofer lines C and D, corresponding to didymium, and a less broad one at the end of the green near the line F, corresponding to erbium.

[1] H. Rosenbusch, Mikroscopische Physiographie, Vol. I., 3d ed., 1892, p. 266.
[2] Am. Jour. Sci. 3, vol. 37, 1889, pp. 109 114. Zeitschr. für Kryst., vol. 19, 1891, p. 78.
[3] Zeitschr. für Kryst., vol. 12, 1887, p. 264.

CHEMICAL MOLECULAR CONSTITUTION OF MONAZITE.

Penfield,[1] in his analyses of Connecticut, North Carolina, and Virginia monazite (see anal. Nos. 30, 31, 32, 33; p. 20), deduces the relation

$$(Ce, La, Di)_2O_3 : P_2O_5 = 1:1$$
$$ThO_2 : SiO_2 = 1:1$$

The former corresponds to the normal phosphate of the cerium metals ($R_2P_2O_3$); the latter corresponds to that of normal thorium silicate, which, in combination with a small percentage of water, makes the mineral thorite or orangite ($ThSio_4H_2O$). He concludes, then, that monazite is essentially a normal phosphate of the cerium metals, in which thorium silicate is present in varying proportions as an impurity in the form of the mineral thorite or orangite.

Dunnington[2] had somewhat previously come to the same conclusion.

Rammelsberg's[3] formula of thorium-free monazite from Arendal, Norway, was $R_2P_2O_8 = (Ce, La, Di)_2P_2O_8$, thus agreeing with Penfield.

Blomstrand,[4] from his analyses of Norwegian and Siberian monazite (see anal. No. 1-10, 13–15, pp. 17, 18), concludes that the mineral is a normal tribasic phosphate, an excess of bases being combined with SiO_2. Thus: $m(3RO,P_2O_5)+2RO, SiO_2+pH_2O$, where $m=5$ to 20, and p=less than 1 usually.

He does not believe, as Penfield does, that the thoria is originally combined with silicia as thorite, but that it is a primary constituent, present as the phosphate, either in combination with the cerium or as an isomorphous mixture, thus:

$$\overset{IV}{Ce}.\ \overset{III}{Ce}\ (O_3PO)_2 \text{ and } \overset{\|IV}{R}Th\ (O_3PO)_2;$$

and that it is altered to the silicate by siliceous waters.

[1] Am. Jour. Sci. (3), vol. 24, 1882, p. 250: vol. 36, 1888, p. 322. Zeitschr. für Kryst., vol. 7, 1883, p. 366; vol. 17, 1890, p. 407.
[2] Am. Chem. Jour., vol. 4, 1882, p. 138.
[3] Zeitschr. Deutsch. geol., Gesell. Berlin. vol. 29, 1877, p. 79. Zeitschr. für Kryst., vol. 3, 1879, p. 101.
[4] Zeitschr. für Kryst., vol. 9, 1887, p. 160; vol. 20, 1892, p. 367.

Rammelsberg[1] has explained the analyses of Kersten and Hermann (see anal. Nos. 19, 20, p. 18), respectively, by the formulæ:

$$\left\{\begin{matrix} 5\ R^3 P^2 O^8 \\ Th^2 P^2 O^9 \end{matrix}\right\} \text{ and } \left\{\begin{matrix} 3\ R^3 P^2 O^8 \\ Th^3 P^4 O^{10} \end{matrix}\right\}$$

which does not, however, appear to express a constant molecular constitution.

ARTIFICIAL PRODUCTION OF MONAZITE.

In 1875 Radominsky[2] produced monazite artificially by treating a solution of impure cerium salt with sodium phosphate, adding an excess of chloride of cerium, and heating to redness. After cooling and crystallization, long yellow prisms with striated surfaces were formed. The specific gravity was 5.09, and the compound, by analysis, was found to agree in composition with that of the mineral monazite.

GEOLOGICAL AND GEOGRAPHICAL OCCURRENCE.

The following table presents the salient features of the geographical, geological, and mineralogical occurrences of monazite. All known localities at which the mineral monazite and its equivalents, turnerite, cryptolite, etc., have been found up to the present time are tabulated here. It is placed at the beginning of this chapter as a general introduction, and for the purpose of convenient reference, to what is to follow.

Conditions of occurrence of monazite.

Localities.	Country Rocks.	Associated Minerals.
UNITED STATES.		
East Blue Hill, Me	Gneiss	
Wakefield, N H	do	Rutile, cassiterite. (?)
Westerly, R. I	Granite	
Narragansett Pier, R. I	do	
Westford, Mass	Gneiss	Xenotime.
Ayer, Mass	do	Zircon, rutile.
Norwich, Conn	do	Sillimanite.
Chester, Conn	do	do
Watertown, Conn	Granite	(In albite) Apatite, zircon, tourmaline.
Portland, Conn		
Yorktown, N. Y		Sillimanite.
New Speedway, along Harlem river, New York City		Xenotime.
Amelia Court House, Va	Albitic granite	Microlite, amazonite, beryl, apatite, orthite, columbite, manganese tantalate.

[1]Handbuch der mineral. Chemie. 1875, p. 305.
[2]Comptes Rendus, vol. 80, 1875, p. 305.

Localities.	Country Rocks.	Associated Minerals.
UNITED STATES.—Continued.		
Deake mica mine, Mitchell county, N. C.	Mica schist	Autunite, uraninite, gummite, garnet.
Ray mica mine, Yancey county, N. C.		(In orthoclase.) Beryl.
Mars Hill, Madison county, N. C.		garnet.
Boomer, Wilkes county, N. C.		Quartz, garnet, zircon, rutile, magnetite, ilmenite.
Milholland's Mill, Alexander county, N. C.	Garnetiferous mica schist.	Rutile.
Emerald and hiddenite mine, Alexander county, N. C.		In quartz.
Burke, Rutherford, Cleveland, Polk, Catawba, and Lincoln counties, N. C.	In gneiss, and stream placers	Quartz, garnet, zircon, rutile, brookite, xenotime, fergusonite, corundum, epidote, beryl, cyanite, magnetite, pyrite, menaccanite.
Crowders Mountain, Gaston county, N. C		
Todd's Branch, Mecklenburg county, N. C	Gold placers	Garnet, zircon, diamond...
Spartanburg and Greenville counties, S. C	Gneiss, and stream placers	(Same as Burke, etc. counties, N. C.)
"The Glades," Hall county, Ga	Gold placers	Quartz, rutile, garnet, etc.
CANADA.		
Villeneuve mica mine, Ottawa county, Quebec	Pegmatite	Garnet, tourmaline, uraninite.
SOUTH AMERICA.		
Rio Chico, Antioquia, United States of Columbia	Gold placers	
Alcobaca, Province of Bahia, Brazil	Beach sands	
Caravellas, Province of Bahia, Brazil	do	
Salabró, Province of Bahia, Brazil	Diamond sands	Quartz, zircon, garnet, disthene, staurolite, corundum.
Province of Minas Geraes	do	Magnetite, ilmenite, pyrite.
Province of Minas Graes, Rio de Janeiro, and São Palo, Brazil.	Gold placers	
Provinces of Bahia, Minas Geraes, Rio de Janeiro, and São Palo, Brazil	Porphyritic granulitic, and schistose gneisses, red syenite, granite dikes...	Apatite, magnetite, ilmenite, rutile, garnet, zircon, Sillimanite.
Buenos Ayres, Argentine Republic	River sands	Zircon.
Cordoba, Argentine Republic.	Gneiss and granite...	
ENGLAND.		
Cornwall	Clay slates	Quartz, albite.
SWEDEN.		
Hölma		
Kårarfvet	Albitic granite	Gadolinite, hjelmite, emerald.
Johannisberg	Cobalt ore	
NORWAY.		
Dillingsö, Moss, Lönnesby, Arendal, Narestoe, Hitteroe, Hvalö	Pegmatite	
Arendal and Midbö		Cryptolite in apatite.
Noterö	Granite	In feldspar, enveloped by orthite.
Helle		
FINNISH LAPMARK.		
Ivalo	Gold sands	Zircon.

Localities.	Country Rocks.	Associated Minerals.
RUSSIA.		
Ilmen Mountains	Albitic granite	Zircon, columbite, samarskite.
Sanarka River	Placers	
BELGIUM.		
Nil St. Vincent		
FRANCE.		
Le Puys, near St. Christophe, Dauphine		Adularia, crichtonite, sphene, anatase.
SWITZERLAND.		
Binnenthal		
Olivone, near Mte. Camperio	Quartz vein, traversing mica schist.	Rutile.
Tessin		
Perdatsch		
Santa Brigritta, near Ruaras, Tavetsch Valley.		
GERMANY.		
Laacher See, near Coblentz	Druse in sanadine bomb.	
AUSTRIA.		
Josephinenhuette, Riesengebirge, Silesia	Pegmatite	(In black mica.) Ilmenite, fergusonite, yttrium spar, zircon.
Schreiberhau, Silesia		Gadolinite, yttrium-spar, xenotime, fergusonite.
Schüttenhofen, Bohemia	Pegmatite	Apatite.
Pisek, Bohemia		In beryl and feldspar.
AUSTRALIA.		
Vegetable Creek, County Gough, New South Wales.		

Monazite is an accessory constituent of the granite eruptives and their derived gneisses. It has been found in these rocks over widely separated areas of the earth's surface, and further search and study is liable to reveal its probable universal presence, in varying proportions, in most granites and granite gneisses. Thus Derby[1] has found monazite as a constant accessory constituent in the porphyritic, granulitic, and schistose gneisses of the provinces of Bahia, Minas Geraes, Rio de Janeiro, and São Palo, in Brazil, representing 300 miles along the axis of the great gneiss region of the Maritime Mountains. The granite dikes, intersecting the gneiss, also carry monazite.

The gneisses of the South Mountain region in North Carolina, covering an area of some 2,000 square miles, in Burke, McDowell,

[1]Am. Jour. Sci., Vol. 37, 1889, pp. 109-114.

Rutherford, Cleveland, Polk, Catawba, Lincoln, and Gaston counties, and extending into Spartanburg and Greenville counties, S. C., have been shown to contain monazite.[1] I have since identified the mineral in the thin sections of several specimens of mica gneiss collected in that locality. The rocks are granitic mica gneisses, hornblende gneisses, which approach more nearly to diorite gneisses, and pegmatites. (See map. Plate II.)

Monazite has recently been found in Hall county, Georgia, near "The Glades," a post-office about 10 miles northeast of Gainesville, on the north side of the Chattahoochee river. It occurs in the gold placers of Flat creek and its tributaries, the Glade, Stockeneter, Hamilton and Huram branches.

Derby,[2] by examining the heavy residues of a number of hand specimens, selected at random from the collection in the National Museum, of Washington, D. C., described the occurrence of monazite in certain granites and gneisses of Maine, New Hampshire, Rhode Island, and Massachusetts.

The monazite of Chester, Portland, and Watertown, Conn., is an accessory constituent of the granite and gneisses. In Amelia county, Va., it is found in albitic granite; also in the Ilmen Mountains of Russia.

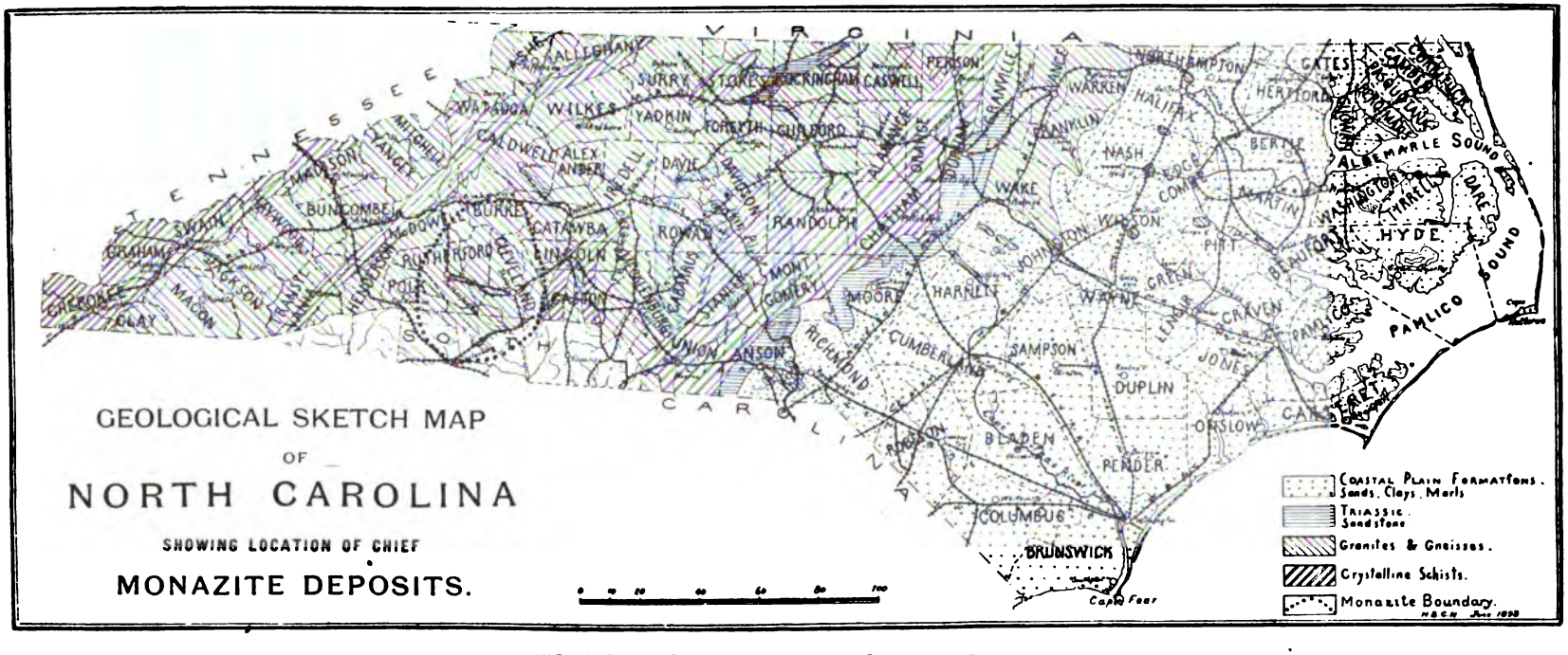
The pegmatites of southern Norway, Silesia, and Bohemia, and of some of the mica mines in Canada and North Carolina, also contain monazite.

Derby (in paper above cited) has found monazite in a red syenite at Serra do Stauba, in the province of Bahia, Brazil. The basic eruptives (diabase, quartz-diorite, mica-diorite, and minette) thus far examined by him in Brazil showed no traces of monazite.

The turnerite of the Laacher See (which is an extinct volcanic crater), near Coblentz, in Prussia, was found in a druse of a sanadine bomb, the only known occurrence of monazite in an undoubted volcanic rock.[3] It was grown into and upon a crystal of orthite.

The turnerite of Olivone, Switzerland, occurs in a quartz vein, 20 to 30 cm. thick, traversing crystalline schists.[4] The percentage

[1]Trans. Am. Inst. Min. Engr., Mar., 1895.
[2]Proc. Rochester, Acad. Sci., vol. 1, 1891, pp. 294-206.
[3]G. von Rath., Poggendorff, Annalen, 1871, Erg.-Bd., 5, p. 413.
[4]G. Sellgman, Zeitschr. für Kryst., vol. 9, 1884, p. 420.



WORKABLE MONAZITE AREA IN NORTH CAROLINA.

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of monazite in these rocks is exceedingly small, often infinitesimal; thus Derby (in paper above cited) states that the granite dikes in the gneiss of Serra de Tingua, near Rio, are rich in the yellow mineral, carrying 0.02 to 0.03 per cent, and a fine-grained granite dike on the outskirts of Rio de Janeiro showed 0.07 per cent monazite.

The cryptolite of Norway occurs as inclusions of very fine, needle-shaped crystals in apatite.

While making a reconnaisance trip through the North Carolina region, the writer, in company with Messrs. H. A. J. Wilkens, E. M., and Jno. R. Kirksey, discovered on June 19th, 1895, the interesting, and so far as known new, occurrence of monazite in cyanite. The locality where first observed was at the Peeler and Ivester placers on a branch of Knob creek, about 16 miles north of Shelby in Cleveland county, N. C. Numerous fragments of a light blue grey cyanite, usually less than one inch, but occasionally as large as three inches in longest dimension, were found in the tailing dumps from the bottom gravels that had been washed in the sluice boxes. The fragments of pure cyanite contained intimately intergrown crystals of monazite, the latter constituting as much as 50 per cent of the mass at times, though some pieces of the cyanite were practically barren. The bed rock and out cropping ledges near here were carefully examined, in the hope of finding the original source of this monazite-bearing cyanite, but without success. It probably occurs in irregular nests and veinlets through the pegmatitic mica gneiss, which forms the country rock.

Derby thinks (in paper above cited) that there is "a reasonable probability that zircon, and to a less degree monazite, may prove to be guide minerals by which eruptives and their derivatives can be certainly identified, no matter what degree of alteration they may have suffered."

Monazite has not been found in the sedimentary rocks, although it may be present in some of these as a secondary mineral of transportation.

The economically valuable deposits of monazite are found in the placer sands of streams and rivers, and in the irregular sedi-

mentary sand deposits of old stream beds and bottoms. Plates I. and III. illustrate the occurrence of monazite sands along the upper reaches of a small branch. The decomposition and disintegration of the crystalline rocks, the original source of the mineral, has proceeded to considerable depths, particularly in the southern, unglaciated countries. By erosion and secular movement the material is deposited in the stream beds and there undergoes a natural process of sorting and concentration, the heavy minerals being deposited first and together. The richer portions of these stream deposits are thus found near the head waters. Such deposits have been described from North and South Carolina in the United States, from Brazil, and from the Sanarka river in Russia.

The beach sand deposits along the coast of Brazil, in the province of Bahia, have a similar explanation, the concentration there being brought about by the action of the waves.

ACCESSORY MINERALS.

The main constituent of the granitic rocks (quartz, feldspar, and mica) all contain the monazite as intergrowths, though it appears to be more generally confined to the feldspar.

Zircon may be regarded as a constant associate; in fact, it is even a more important and general accessory constituent of the rocks than monazite. Among the other usual associated minerals, of coeval origin with the monazite, are xenotime, fergusonite, sphene, rutile, brookite, ilmenite, cassiterite, magnetite, and apatite; sometimes beryl, tourmaline, cyanite, corundum, columbite, samarskite, uraninite, gummite, autunite, gadolinite, hjelmite, and orthite.

The association of monazite with orthite, gadolinite, samarskite; uraninite, and hjelmite is interesting as suggesting the possibility of some genetic relationship.

Among the principal secondary and metamorphic minerals found in association with monazite are rutile, brookite, anatase, epidote, orthite, garnet, sillimanite, and staurolite.

ECONOMIC USE.

The economic value of monazite lies in the incandescent proper-

WASHING GRAVEL AND SAND IN STREAM BEDS FOR MONAZITE, LATTIMORE MINE.

THIS VALLEY, 3 MILES N. E. OF SHELBY, IS 100 TO 200 YARDS WIDE, AND ITS UNDERLYING GRAVEL EVERYWHERE YIELDS MONAZITE.

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areas over which such workable deposits have been found up to the present time are quite limited in number and extent. In the United States the placer deposits of North and South Carolina stand alone. This area includes between 1600 and 2000 square miles, situated in Burke, McDowell, Rutherford, Cleveland, and Polk counties, N. C., and the northern part of Spartanburg county, S. C. The principal deposits of this region are found along the waters of Silver, South Muddy, and North Muddy creeks, and Henrys and Jacobs Forks of the Catawba river in McDowell and Burke counties; the Second Broad river in McDowell and Rutherford counties; and the First Broad river in Rutherford and Cleveland counties, N. C., and Spartanburg county, S. C. These streams have their sources in the South Mountains, an eastern outlier of the Blue Ridge. The country rock is granitic biotite gneiss and dioritic hornblende gneiss, intersected nearly at right angles to the schistosity by a parallel system of small auriferous quartz veins, striking about N. 70° E., and dipping steeply to the N.W. Most of the stream deposits of this region have been worked for placer gold. The existence of monazite in commercial quantities here was first established by Mr. W. E. Hidden, in 1879. The thickness of these stream gravel deposits is from 1 to 2 feet, and the width of the mountain streams in which they occur is seldom over 12 feet. The percentage of monazite in the original sand is very variable, from an infinitesimal quantity up to 1 or 2 per cent. The deposits are naturally richer near the head waters of the streams.

The monazite is won by washing the sand and gravel in sluice boxes exactly after the manner that placer gold is worked. The sluice boxes are about 8 feet long by 20 inches wide by 20 inches deep. Two men work at a box, the one charging the gravel on a perforated plate fixed in the upper end of the box, the other one working the contents up and down with a gravel fork or perforated shovel in order to float off the lighter sands. These boxes are cleaned out at the end of the day's work, the washed and concentrated monazite being collected and dried. Magnetite, if present, is eliminated from the dried sand by treatment with a large hand magnet. Many of the heavy minerals, such as zir-

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MINING AND WASHING GRAVEL BEDS FOR MONAZITE, LATTIMORE MINE.

THE GRAVEL, 2-4 FEET THICK, LIES ON GRAY GNEISS, AND IS IN TURN OVERLAIN BY 2-4 FEET OF SAND AND LOAM.

con, menaccanite, rutile, brookite, corundum, garnet, etc., can not be completely eliminated. The commercially prepared sand, therefore, after washing thoroughly and treating with a hand magnet, is not *pure* monazite. A cleaned sand containing from 65 to 70 per cent. monazite is considered of good quality. From 20 to 35 pounds of cleaned monazite sand per hand, that is, from 40 to 70 pounds to the box, is considered a good day's work.

But very few regular mining operations are carried on in the region. As a rule each farmer mines his own monazite deposit and sells the product to local buyers, often at some country store in exchange for merchandise.

At the present time the monazite in the stream beds has been practically exhausted, with few exceptions, and the majority of the workings are in the gravel deposits of the adjoining bottoms. These deposits are mined by sinking pits about 8 feet square to the bed rock and raising the gravel by hand labor to a sluice box at the mouth of the pit. The overlay is thrown away excepting in cases where it contains any sandy or gritty material. The pits are carried forward in parrallel lines, separated by narrow belts of tailing dumps, similar to the methods pursued in placer gold mining. At the Blanton and Lattimore mines on Hickory creek, 2 miles northeast of Shelby, Cleveland county, N. C., the bottom is 300 to 400 feet wide, and has been partially worked for a distance of one-fourth of a mile along the creek. The overlay is from 3 to 4 feet, and the gravel bed from 1 to 3 feet thick. (See Plate IV.)

The methods of mining and cleaning are much more systematic in Spartanburg county, S. C., than in the North Carolina regions. Although the raw material contains on an average fully as much garnet, rutile, titanic iron ore, etc., as that in the North Carolina mines, a much better finished product is obtained, and more economically, by making several grades. Two boxs are used in washing the gravel, one below the other. The gravel is charged on a perforated plate at the head of the upper box, and the clean-up from this box is so thoroughly washed as to give a high grade sand, often up to 85 per cent. pure. The tailings discharge

directly into the lower box, where they are rewashed, giving a second grade sand. At times the material passes through as many as five washing treatments in the sluice boxes. Even after these grades are obtained as clean as possible by washing, the material, after being thoroughly dried, is further cleaned by pouring from a cup, or a small spout in a bin, in a fine, steady stream from a height of about 4 feet, on a level platform; the lighter quartz and black sand with the fine-grained monazite (tailings) falls on the periphery of the conical pile and is constantly brushed aside with hand brushes; these tailings are aftewards rewashed. Instead of pouring and brushing, the material is sometimes treated in a winnowing machine similar to that used in separating chaff from wheat.

Although the best grade of sand is as high as 85 per cent. pure, its quantitative proportion is small as compared with the second and other inferior grades, and there is always considerable loss of monazite in the various tailings. It is impossible to conduct this washing process without loss of monazite, and equally impossible to make a perfect separation of the garnet, rutile, titanic iron ore, etc., even in the best grades. The additional cost of such rewashing and rehandling must also be taken into consideration.

If the material washed contains gold, the same will be collected with the monazite in concentrating. It may frequently pay to separate it, which can easily be accomplished by treating the whole mass over again in a riffle box with quicksilver.

It has been shown that the monazite occurs as an accessory constituent of the country rock, and that the latter is decomposed to considerable depths, sometimes as much as 100 feet. On account of the minute percentage of monazite in the mother rock, it is usually impracticable to economically work the same in place, by such a process as hydraulicking and sluicing, for instance. However, even hillside mining has been resorted to. Such is the case at the Pheifer mine, in Cleveland county, N. C., 2 miles northeast of Shelby. (See Plate V.) The country rock is a coarse mica (muscovite and biotite) gneiss, and the small

DIGGING AND WASHING HILL-SIDE SOIL FOR MONAZITE.

PHEIFER MINE, 8 MILES N. E. OF SHELBY. THE SOIL, 1-4 FEET THICK, HAS BEEN FORMED FROM MONAZITE BEARING GNEISS, IN PLACE.

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monazite crystals may at times be distinctly seen, unaided by a magnifying glass, in this rock. It is very little decomposed and still quite hard, and the material that is mined for monazite is the overlying soil and subsoil, which is from 4 to 6 feet thick. This is loaded on wheelbarrows and transported to the sluice boxes below the water race. The yield is fairly good, and the product very clean, though the cost of working, of which, unfortunately, figures could not be obtained, must be considerably in excess of that of bottom mining. Where the rock contains sufficient gold, as it somtimes does, to be operated as a gold mine, there is no reason why the monazite can not be saved as a valuable by-product.

OUTPUT AND VALUE OF MONAZITE IN THE UNITED STATES.

As the percentage of thoria is variable in different sands, the value of the sand consequently varies in a measure also. It is stated that the transparent greenish and yellowish brown varieties are often rich in thoria, but this can not be depended on.

Hidden[1] has suggested that the difference in cleavage may be an indication of the presence or absence of thoria, that crystals with the cleavage best developed parallel to $\infty P\bar{\infty}$ are the pure phosphate of the cerium earths, free from thoria, while those in which the cleavage is best developed parallel to 0P, contain thoria. But the cleavage is rarely observable in the rolled grains, and if it were the above statement is by no means a proven fact. He also makes the suggestion (in paper above cited) that the density may afford a test of the approximate comparative amount of thoria present, and in support of this he mentions the following examples:

Relation of thoria contents to density in monazite.

Specific gravity.	ThO_2	Localities.	References.
	Per cent.		
5.30	14.23	Amelia Court-House, Va	Table, p. 20, anal. No. 32.
5.20-5.25	8.25	Portland, Conn	Table, p. 20, anal. No. 30.
5.10	6.49	Burke County, N. C	Table, p. 20, anal. No. 31.

However, this will scarcely hold, for in other instances monazite of the specific gravity 4.64 has been shown to contain

[1]Am. Jour. Sci., vol. 32, 1886, p. 207. Zeitschr. für Kryst., vol. 12, 1887, p. 507.

as much as 9.20 per cent. thoria (from Moss, Norway; see p. 17, anal. No. 4); and again, monazite of the specific gravity 5.19 contained but 3.18 per cent. thoria (from Dillingsö, Norway; see p. 17, anal. No. 2). On the whole, there is no method of determining even the probable percentage of thoria, excepting by chemical analysis. Some monazite contains practically no thoria. The best North Carolina sands (highest in thoria) came from Burke and Cleveland counties. Some of the highest grade sand from Brindletown, Burke county, runs from 4 to 6.60 per cent. thoria; sand from Gum Branch, McDowell county, is reported to run 3.30 per cent; sand from the vicinity of Bellwood and Carpenter's Knob, in Cleveland county, runs from 5 to 6.30 per cent. The fluctuation of the thoria percentage is, however, considerable even in the same locality. It also depends, of course, in a measure on the degree of concentration of the sand.

The price of North Carolina monazite has varied from 25 cents per pound in 1887 to as low as 3 cents for inferior grades and 6 to 10 cents for the best grades in 1894 and 1895. It is only during the past two years that the mining and concentration of monazite sand in the South Mountain region has grown to a regular industry, and it is at present progressing with increased vigor. In 1887 Mr. Hidden shipped from the Brindletown district, in Burke county, N. C., 12 tons of monazite sand. And during 1888 and 1889 a number of tons (exact quantity unknown) were shipped from North Carolina to the Welsbach Light Company in Philadelphia. The product and value of the sand during 1893 and 1894 is given below. It was shipped in part to the Welsbach Light Company and in part to Europe (Germany and Austria).

Product and value of monazite in 1893 *and* 1894.

1893.		Value at mines.	1894.		Value at mines.
Quantity.	Price.		Quantity.	Price.	
Pounds.	*Cents.*		*Pounds.*	*Cents.*	
110,000	6	$6,600	460,000	.....	$31,050
20,000	5	1,600	80,000	.....	4,800
			6,855	.....	343
130,000	.....	7,600	546,855	.....	36,193

In Brazil considerable deposits of monazite occur in the beach sands along the seashore. The largest of these is found in the extreme southern part of the Province of Bahia, near the island of Alcobaca. The surf as it breaks against the cliffs washes away the lighter earths and minerals, leaving naturally concentrated deposits of monazite along the beach. Sacks filled with this sand were shipped to New York in 1885, the deposit having been taken for tin ore. Its true character was, however, soon recognized, and since then a number of tons have been shipped in the natural state, without any further concentration or treatment, as ballast, mainly to the European markets. It is reported to contain 3 to 4 per cent thoria. Very little exact information concerning these Brazilian deposits is at present available. Monazite has also been found in the gold and diamond placers of the Provinces of Bahia (Salabro and Caravellas), Minas Geraes (Diamantia), Rio de Janeiro and São Paulo. It has been found in the river sands of Buenos Ayres, Argentine Republic, and also in the gold placers of Rio Chico, at Antioquia, in the United States of of Colombia.

In the Ural Mountains of Russia monazite is found in the Bakakui placers of the Sanarka River. The placer gold mines of Siberia are reported to contain monazite.

Economic deposits of monazite are also reported to exist in the pegmatite dikes of Southern Norway. It is picked by the miners while sorting feldspar at the mines. It is not known to exist in placer deposits. The annual output is stated to be not more than one ton, which is shipped mainly to Germany.[1]

[1]U. S. Consular Report; vol. 48, No. 179, Aug. 1895, p. 550.

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NORTH CAROLINA GEOLOGICAL SURVEY

J. A. HOLMES, STATE GEOLOGIST

BULLETIN No. 10

GOLD MINING IN NORTH CAROLINA

AND

ADJACENT SOUTH APPALACHIAN REGIONS

BY

HENRY B. C. NITZE

AND

H. A. J. WILKENS

RALEIGH

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STATE GEOLOGIST.

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LETTER OF TRANSMITTAL.

To His Excellency, Hon. D. L. Russell,

Governor of North Carolina.

Sir:—I have the honor to transmit for publication as bulletin 10 of the Geological Survey series, a report on the subject of Gold Mining and Mining Methods in North Carolina and adjacent South Appalachian regions. The Survey has received many requests for information concerning this subject, and it is in response to these that I recommend the publication of this report. Many applications for copies of it have been received in advance of its appearance.

Yours obediently,

J. A. Holmes,

State Geologist.

Raleigh, N. C.,

July 1, 1897.

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PREFACE.

During the past few years the Survey has received from persons interested in gold mining in North Carolina, numerous inquiries concerning the mining and metallurgical methods which have proven most successful in operating gold mines in this and other South Appalachian regions. In response to these inquiries, an investigation was undertaken of this subject in 1895, by Mr. H. B. C. Nitze, of the Survey, and Mr. H. A. J. Wilkens, a mining expert of Baltimore, who visited during that year the more important mining regions in North Carolina and other Southern States. A preliminary report of their examinations was read at the Atlanta meeting of the American Institute of Mining Engineers (October, 1895), and was published in the Transactions of the Institute for that year.

In the present publication that paper has been partly reproduced, but it has been largely rewritten, elaborated and brought down to the end of 1896. No attempt has been made to describe all of the mines or even to present detailed descriptions of all of the more important mining regions to be found in North Carolina and adjacent States. Only such mining and metallurgical methods practiced in this and the other States are here described as it is believed will be found useful in a study of the best methods for use in the development of the North Carolina gold fields. This report may be regarded as being in a measure supplemental to Bulletin 3 (Gold Deposits of North Carolina), published by the Survey in 1896, which described with more detail the gold-mining regions in this State.

The descriptions given in the report are based almost wholly upon the personal examinations of Messrs. Nitze and Wilkens. They have, however, made use of data relating to the different mining regions to be found in Mr. Geo. F. Becker's valuable "Reconnoissance of the Gold Fields of the Southern Appalachians," and the reports by the several State Geological Surveys, the sources of information being indicated in each case by footnotes. Persons desiring to consult other publications

relating to this field will find a full bibliography in the above-mentioned report of Mr. Becker's, published by the U. S. Geological Survey.

Messrs. Nitze and Wilkens have been aided in the preparation of their statement concerning the Haile mine in South Carolina by Mr. A. Thies. Capt. John Wilkes, of the Mecklenburg Iron Works, Charlotte, N. C., has also aided them by the loan of drawings, maps and in other ways. Mr. Geo. B. Hanna, of the U. S. Assay Office, at Charlotte, N. C., has kindly furnished numerous notes concerning the history of mining and metallurgical methods in the entire South Appalachian region. In behalf of the Survey and of the authors, I desire to thank these gentlemen and many others, in different parts of the region, who have in various ways rendered assistance in the collection and preparation of information for this report. I desire further to thank the editors of The Transactions of the American Institute of Mining Engineers and The Engineering Magazine for permission to use electrotypes of plates prepared for those publications.

One of the existing needs of the North Carolina gold field is the establishment at central points in this region of practical plants that will successfully treat the low-grade sulphuret ores—plants that will do custom work at reasonable prices, and where individual miners can ship their ore and be paid for the same according to its value, as is the case in the great mining regions of the West.

J. A. Holmes.

GOLD MINING IN NORTH CAROLINA AND ADJACENT SOUTH APPALACHIAN REGIONS.

By H. B. C. Nitze and H. A. J. Wilkens.

CHAPTER I.

GEOGRAPHICAL AND GEOLOGICAL DESCRIPTION OF THE GOLD BELTS.

The gold fields of the Southern Appalachians are situated in the area of the crystalline rocks extending from the vicinity of Washington in a general southwesterly direction, through the piedmont and mountain regions of Maryland, Virginia, North Carolina, Tennessee, South Carolina, Georgia, and Alabama, to the vicinity of Montgomery.

The greatest width of the belt, as a whole, is attained in North Carolina, South Carolina and Georgia, where it is from 100 to 150 miles, narrowing down in Virginia and Maryland on the northeast and in Alabama on the southwest (see map, fig. 1).

In chapters III and IV the gold-mining counties of these States are given.

The general term crystalline rocks includes gneisses, argillaceous, hydro-micaceous, chloritic, siliceous and other schists and slates, limestone, granite, diorite, diabase and other eruptives, as well as certain volcanic porphyries, etc., and pyroclastic breccias. The age of these rocks is Archæan, Algonkian, and possibly in part Paleozoic. On the east they are covered by the Coastal Plain and in places by small patches of the Jura-trias (Newark), which latter also occur within the area in small isolated basins, notably in Virginia. On the west they are bordered by the Paleozoic rocks.

The rocks of the gold belt are decomposed to depths often reaching 50 and 100 feet. Mr. Becker has proposed and used the term "saprolite,"[1] signifying literally "rotten rock," as a general name for such thoroughly decomposed, earthy, but untransported rock.

For geological reasons and for descriptive convenience this gold belt

[1] "Reconnoissance of the Gold Fields of the Southern Appalachians, by G. F. Becker, *Sixteenth Annual Report of the U. S. Geological Survey*, 1894-5, part iii, pp. 289-90.

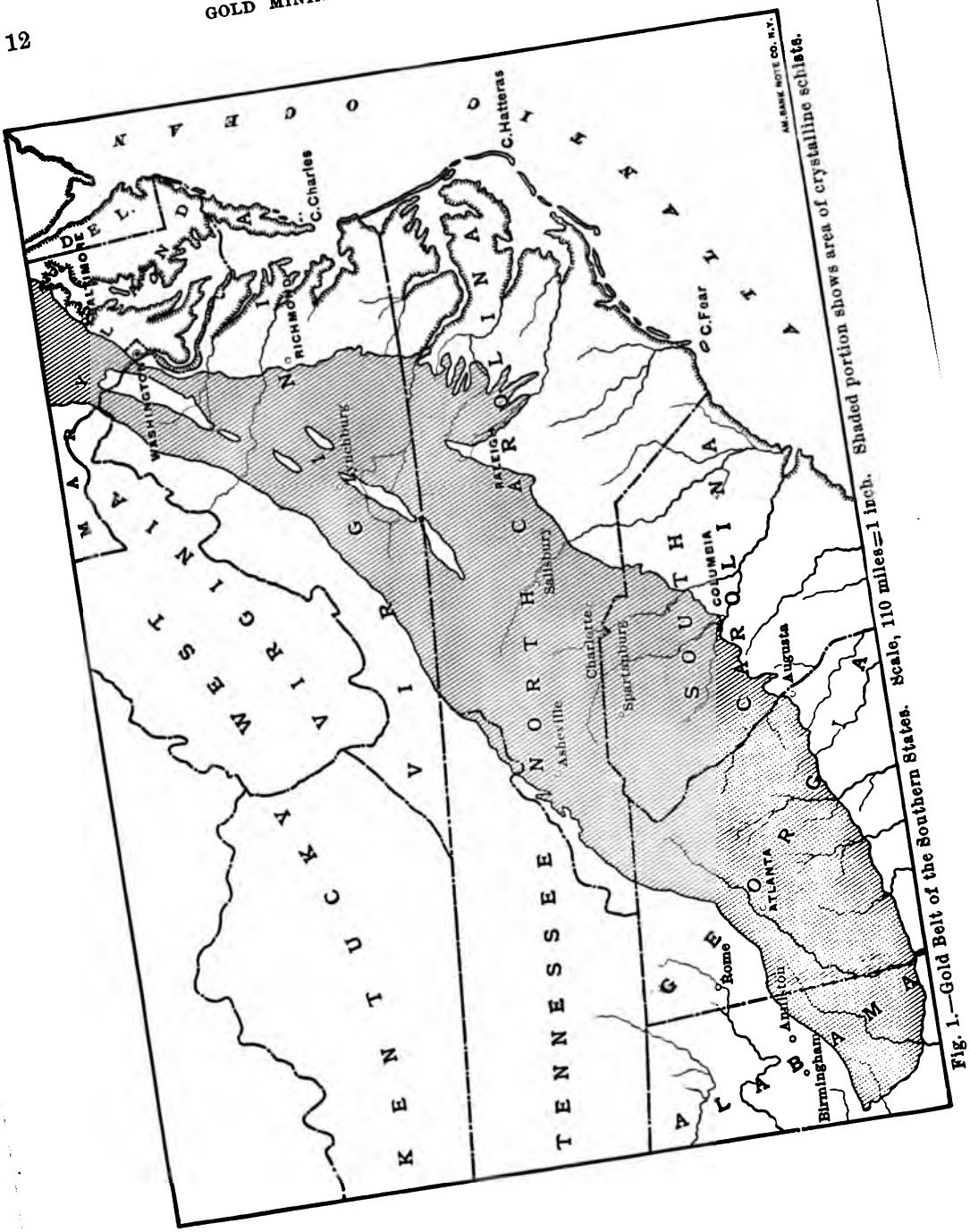

Fig. 1.—Gold Belt of the Southern States. Scale, 110 miles=1 inch. Shaded portion shows area of crystalline schists.

of the Southern Appalachians is differentiated into the following component belts:

1. The Virginia Belt.
2. The Eastern Carolina Belt.
3. The Carolina Belt.
4. The South Mountain Belt.
5. The Georgia Belt.
6. The Alabama Belt.

Other divisions might be made as, for instance, the isolated belts of auriferous rocks west of the Blue Ridge in Virginia, North Carolina, Georgia and Tennessee, and various minor belts in Georgia and Alabama; but such subdivision is unnecessary for the purposes of this paper.

In Bulletin 3, "The Gold Deposits of North Carolina," the Carolina Belt has been differentiated into the Carolina Slate, the Carolina Igneous and the Kings Mountain belts. For the purpose of this paper, however, where the geological descriptions of these various belts can only be briefly taken up, the above six main divisions will suffice, and for fuller and more detailed descriptions the reader is referred to the following papers:

"Reports on the Surveys of South Carolina," by O. M. Lieber, Columbia, S. C., 1856, 1857, 1858, and 1859.

"A Reconnoissance of the Gold Fields of the Southern Appalachians," by George F. Becker.[1]

"The Gold Deposits of North Carolina," by H. B. C. Nitze and G. B. Hanna.[2]

"The Lower Gold Belt of Alabama," by William B. Phillips.[3]

"Mineral Resources of the Upper Gold Belt (of Ala.)," by Wm. M. Brewer and others.[4]

Work has been in progress by the Geological Surveys of Georgia and Alabama on the gold fields, and reports from these respective bureaus are expected to be published shortly.

1. THE VIRGINIA BELT.

This belt begins in Montgomery county, Maryland, and extends in a southwesterly direction, parallel to and on the east side of the Blue Ridge, to the North Carolina line. The best and most reliable, though incomplete, information regarding the geology of this region is given in the early reports of Prof. William B. Rogers (1835, 1836 and 1840).[5]

The width of the belt is from 9 to 20 miles, covering an area of some 4000 square miles, and its best developed portion is in Fauquier, Cul-

[1] *U. S. Geological Survey, Sixteenth Annual Report*, 1894–95, part iii, pp. 251–331.
[2] *North Carolina Geological Survey*, Bull. No. 3, 1896.
[3] *Geological Survey of Alabama*, Bull. No. 3, 1892.
[4] *Geological Survey of Alabama*, Bull. No. 5, 1896.
[5] *The Geology of the Virginias*, D. Appleton & Co., New York, 1884, pp. 74–80, 131–132, 453–460.

peper, Stafford, Orange, Spottsylvania, Louisa, Fluvanna, Goochland and Buckingham counties.

THE COUNTRY-ROCKS.

The rocks of the Virginia belt are mica-gneisses and schists, often garnetiferous, hydro-micaceous and chloritic. The strike is N. 20°–30° E., and the dip easterly at varying angles. Mr. S. F. Emmons[1] gives the prevailing strike in Montgomery county, Maryland, as north and south, and the dip nearly vertical or very slightly inclined to the eastward. Granite and diabase dikes occur in the region, and these are sometimes sheared. In some private notes on the Arminius pyrite mine, in Louisa county, Va., Mr. Becker says:

"The principal country rock is a series of micaceous schists. . . . . Indications are not wanting that a portion of these schists is of sedimentary origin. . . . . On the other hand, it is equally certain that the most prominent characteristics of the schists are of dynamic origin. . . . Much of the schist looks as if it were derived dynamically from granite."

THE QUARTZ-VEINS.

The auriferous quartz-veins conform in the main to the strike and dip of the enclosing rock. However, their origin is not coeval, the schistose structure antedating the formation of the veins. Neither must their approximate conformity to the country be taken in the absolute sense, for they often cut the schists at small angles both in dip and strike. The structure of the veins is irregularly lenticular, varying from a few inches to several feet in thickness. The wall-rock is often impregnated with auriferous pyrites to considerable extent. Some of these veins are of remarkable persistency and continuity, as, for instance, the Fisher lode in Louisa county, which has been opened for a distance of some five miles along the strike to a maximum depth of 220 feet by the Warren Hill, Louisa, Slate Hill, Luce and Harris mines.

The gravel placer deposits of the Virginia belt are in all respects similar to those of other gold regions.

A small isolated gold belt is situated on the west side of the Blue Ridge in Montgomery, Floyd and Grayson counties, but it is of little economical importance and will not warrant more than this passing mention. The auriferous copper ores of Ashe and Watauga counties, N. C., also appear to belong here.

2. THE EASTERN CAROLINA BELT.

This forms a small and narrow area in Halifax, Warren, Nash and Franklin counties. It is covered on the east by the Coastal Plain and

[1] "Notes on the Gold-Deposits of Montgomery county, Md.," by S. F. Emmons, *Trans. Am. Inst. Min. Eng.*, xviii, 391-411.

bounded on the west by the Louisburg granite. The country rock is diorite, in great part sheared to a chloritic schist (as at the Mann-Arrington mine). The strike of the schists is N. 50°–60° E., and the dip 25°–40° S.E. Other intrusives, such as diabase, occur in the region.

THE QUARTZ-VEINS.—These occur (1) as lenses, from minute size up to 12 inches in thickness, interlaminated in the schists or cutting them at small angles; (2) as a reticulated network in the massive rocks. It is stated that the saprolites are auriferous over large areas and will repay hydraulic mining.

3. THE CAROLINA BELT.

This belt is one of the most extensive and important in the Southern Appalachians, though lying far to the east of the Blue Ridge. It is situated in the central Piedmont region, and extends from the Virginia line in a southwesterly direction across the central part of North Carolina into the northern part of South Carolina, where it sinks beneath the Coastal Plain, making its re-appearance in Abbeville county, S. C., and in Wilkes, McDuffie and adjacent counties in Georgia, near Augusta. There are no mountain chains in the Carolina belt, the only prominences of consequence being a low range of hills known as the Uharie mountains, in Montgomery county, N. C., and the isolated peaks of Crowders and Kings mountains in Gaston county, N. C., extending into York county, S. C.

The belt varies in width from 8 to 50 miles; it is bounded on the east by the Jura-trias (Newark) and the coastal plain formations.

THE COUNTRY-ROCKS.

The gold-bearing rocks of the Carolina belt are (1) argillaceous, sericitic and chloritic metamorphosed slates and schists; (2) devitrified ancient volcanics (rhyolite, quartz-porphyry, etc., and pyroclastic breccias); (3) igneous plutonic rocks (granite, diorite, diabase, etc.); (4) siliceous magnesian limestone; (5) sedimentary pre-Jura-trias slates. The Jura-trias conglomerates along the eastern boundary have also been found to contain gold, but not in quantities of economical importance.

The argillaceous and sericitic[1] slates and schists, though in general highly metamorphosed and sheared, show many evidences of sedimentary origin. The siliceous magnesian limestones (Kings mountain, etc.), must be included here. All of these rocks are non-fossiliferous and must be provisionally classed as Algonkian. They are often silicified in varying degrees up to a completeness which renders the rock so

[1] The general term "talc" schists, so often used, is very loosely applied, and generally incorrectly, as the true "talc" schists are comparatively rare; it should, from a mineralogical standpoint, more properly be hydro-mica or sericite schists.

hard that it resists scratching with a knife. The chloritic schists are more truly the crystalline schists, and probably represent the sheared basic eruptives. They are even porphyritic and brecciated in places. They are not so abundant as the argillaceous schists, and are richer in accessory metamorphic minerals, such as garnet and epidote.

The general strike of the schistosity is N. 20°–55° E., and the predominating dip to the N. W. from 55°–85°. In many cases the force producing schistosity and slaty cleavage appears to have acted downward from the N.W., developing normal faulting with but little deformation.

The volcanic rocks occupy irregular patches along the eastern border of the belt, in close proximity to the western edges of the Jura-trias basins. They comprise both acid and basic types. The acid rocks are generally devitrified to such an extent that their real character is no longer recognizable to the naked eye, and they appear as ordinary cherts or hornstones, although flow-structure is at times still discernible. Microscopic examination shows them to belong to the class of rhyolites and quartz-porphyries. They are sometimes sheared into schists, as for instance at the Haile mine, S. C. The basic types are dark green in color and perhaps pyroxenic in composition; they are sometimes massive porphyrites, but more generally sheared into schists. The pyroclastic breccias consist of angular fragments of the acid rhyolites and porphyries in a basic matrix. The age of these ancient volcanics is believed to be pre-Cambrian. They seem to be analogous to, and probably contemporaneous with, similar rocks of the South mountain in Maryland and Pennsylvania, and other points along the Atlantic coast. The igneous plutonic rocks lie on the western side of the central slates; they consist of granites, diorites, gabbros, diabases, etc. In point of age they are supposed to be younger than the slates and schists on the east. Diabase dikes are common in the Carolina belt, and appear in general to have exercised a favorable influence on the richness of the ore-bodies which they intersect; the ores often are richer in the vicinity of the dikes. At the Haile mine, in Lancaster county, S. C., this is very marked.

The sedimentary pre-Jura-trias slates, mentioned above as the fifth class of gold-bearing rocks, are perhaps best developed near Monroe, Union county, N. C., and have therefore been called the Monroe slates. These slates are but little indurated and lie in flat-bedded alternating synclinals and anticlinals. They cover a considerable area, extending from Monroe northward and eastward, and appearing in Stanly and Montgomery counties. They dip under the Jura-trias conglomerate near Polkton, 20 miles east of Monroe, and might be looked upon as Lower Paleozoic; but the absence of fossils, so far as present search has gone, must, for the time being, place them provisionally in the Algonkian.

THE GOLD ORES.

The gold ores in the Carolina belt exist in two principal structural forms: (1) as quartz fissure-veins; (2) as pyritic impregnations, accompanied by irregular stringer-like and lenticular quartz intercalations in the country schists and slates. The fissure-veins in the slates and schists are generally difficult to distinguish as such. Their structure is much more evident in the granitic and other eruptives. In the schists the larger and more regular quartz lodes lie apparently interlaminated with the country, or have the appearance of lenticular intercalations; however, even here they can usually be shown to intersect the schistosity, generally at very low angles.

The age of the ore deposits is later than that of the force which produced schistosity, from the fact that fragmental inclusions of sheared country-rock are not rare in quartz. The fissuring force was, therefore, subsequent to the shearing force. Certain maximum lines of faulting may have been developed, which made room for the larger fissure-veins, on either side of which smaller dislocations formed belts of variable width. It is certainly most natural that, in a rock like slate or schist, the rupturing force should have been exerted along the lines of least resistance, that is, along the cleavage planes, and that the predominating fissures should, therefore, have been formed in that direction. Isolated instances of cross-fissures occur, but they are rare.

A very usual occurrence of the ores is that of irregular, finely-divided disseminations of auriferous sulphurets and fine gold, accompanied by small stringers and lenses of quartz in the country slates and schists, which are usually silicified, at least to some extent. This form of deposit bears close resemblance to the Scandinavian "fahlbands," which are described as belts of schists impregnated with sulphides. In the Southern Appalachian field they form the small and large bodies of low-grade ores (Haile mine, Russell mine, etc.). The shape of these ore-bodies is lenticular; their outline, however, does not necessarily conform with the strike and dip of the schists, but is determined rather by the degree of impregnation. Very often, also, the wall-rock of the quartz fissure-veins is impregnated for some distance with auriferous sulphurets.

The gravel placers of the Carolina belt present no features differing from those of similar deposits in other gold regions.

GENESIS OF THE ORE-BODIES.

No definite proof of metasomatic formation of the ores has been observed; and the most reasonable hypothesis for their formation is that of the ascension and percolation of heated carbonated and alkaline waters carrying silica, metallic elements and sulphides in solution, and the depo-

sition of their mineral contents in the open spaces through which they circulated, by relief of pressure, reduction of temperature, and perhaps certain chemical reactions. The frequent silicification of the slates and schists has been noted, and must be ascribed to this permeation of the silicified waters.

The character of the quartz varies from saccharoidal to vitreous, usually inclining to the latter. The sulphurets are chiefly pyrites; chalcopyrite, galena, mispickel and zinc-blende occur in certain localities, notably at the Silver Hill and Silver Valley mines, in Randolph county, N. C. Copper ores (chalcopyrite) in some of the North Carolina mines are auriferous to such an extent as to make them valuable for gold also, as for instance at the Conrad Hill. Tellurides have been found in very small quantities, as at the Kings Mountain mine, N. C. Among the more common gangue minerals, besides quartz and sulphurets, are chlorite, barite and carbonates.[1]

THE AGE OF THE ORE DEPOSITS.

The formation of the ores took place subsequent to the production of schistosity. The fact that the Jura-trias conglomerates, on the east, contain gold proves that the origin of the gold must have been pre-Jura Triassic. The presence of gold-bearing fissure-veins in the Monroe slates shows that their age must be Algonkian or later. The existence of ore-bodies in the pre-Cambrian volcanic rocks furnishes another clue; and thus it becomes probable that the age of the gold ores in the Carolina belt is Algonkian.

4. THE SOUTH MOUNTAIN BELT.

This belt is situated in the western part of North Carolina, and takes its name from the South mountains, one of the eastern outliers of the Blue Ridge. The principal mining region embraces an area of 250 to 300 square miles, in Burke, McDowell and Rutherford counties, extending from Morganton to near Rutherfordton, a distance of about 25 miles, with an average width of 10 to 12 miles. The gold veins of northern Burke and Caldwell counties on the north, and Cleveland and Polk counties, N. C., on the south, as well as Spartanburg, Greenville and Pickens counties, S. C., might be considered as belonging to this general belt; but no extensive operations have been carried on there.

THE COUNTRY-ROCKS.

In the South mountain region, the crystalline rocks are for the most part Archæan micaceous (biotite) and hornblendic gneisses and schists,

[1] Mr. Becker, in the paper referred to above, pp. 274-278, tabulates no less than 60 gangue minerals, besides quartz, pyrite, and the ordinary products of decomposition.

having an eminently lenticular structure. They are often garnetiferous and contain also many of the rarer accessory minerals, such as zircon, monazite, xenotime, etc. These gneisses are considered to have been igneous granites and diorites, subsequently rendered schistose by dynamo-metamorphism. The general strike of the schistosity is N. 10°–25° W., and the dip 20°–25° N.E. To the northwest of South Muddy creek and Vein mountain, however, the strike is generally N. E. and the dip S. E. This is the case also in the northern part of the general belt, in Caldwell county.

Isolated masses of pyroxenite and amphibolite occur as rounded inclusions or blebs, from less than 1 to nearly 100 feet in diameter, in the gneiss. They are looked upon as basic segregations from the original igneous magma out of which the gneisses were formed. They alter to talc and serpentine.

Pegmatites are of frequent occurrence in the gneisses, and like them their structure is usually lenticular. At several points there are indications of pegmatite dikes. Granite dikes occur in the South mountain region; and in the northern part of the belt, in Caldwell county, a very persistent and continuous dike of aphanitic olivine diabase has been observed. Brown mountain, in the northern part of Burke county, is made of granite.

THE QUARTZ-VEINS.

The auriferous quartz-veins of the South mountain belt form a system of parallel fissures of remarkable regularity, striking N. 60°–70° E. and dipping 70°–80° N.W. Their thickness varies from that of a knife-edge to 4 feet. The great majority are from less than 1 to 3 inches in thickness, lying in zones of scores of small veins; the larger ones (1 to 4 feet) are few and far between. Normal faulting has been observed in a few instances. The ore is quartz, usually of a milky white color, generally saccharoidal and seldom vitreous or glassy. It is often stained brown and is cellular from decomposed sulphurets. The sulphurets are pyrite, galena, chalcopyrite, and zinc-blende. All observations go to show that the vein-matter is formed from ascending mineralized solutions. There is no evidence of the replacement of the country rock by ore.

In the South mountain region proper there are five parallel lines or zones along which these quartz-veins appear to be concentrated:

1. The Morganton zone, passing through Morganton, along Little Silver creek and through the Neighbor's place to North Muddy creek.

2. The Huntsville zone, passing over the southern end of Huntsville mountain.

3. The Pilot mountain zone, passing over Halls knob, Whites knob,

Pilot mountain, Brackettown, and Vein mountain, to and beyond the Second Broad river.

4. The Golden valley zone, passing across the upper end of the Golden valley (valley of the First Broad river) and crossing Cane and Camp creeks to the Second Broad river.

5. The Idler mine zone, about 3 miles north of Rutherfordton.

The great majority of these auriferous quartz-veins are too small to be profitably worked individually. Of the larger and more promising veins which have been worked, the "Nichols," at Vein mountain (18 inches to 3 feet), and the "Idler," near Rutherfordton (22 inches), may be mentioned.

THE PLACER DEPOSITS.

The principal mining ground of the South mountain region is that of the placer deposits. These are of three classes: 1. The gravel deposits of the stream-beds and bottom-lands, deposited by fluviatile action. 2. The gulch and hillside deposits, or accumulations due to secular disintegration and motion induced by frost action and gravity. 3. The upper decomposed layer of the country-rock in place, the saprolites.

In the first class the gravel is water-worn, rounded to subangular, and the deposits are from 1 to 2 feet in thickness. In the second class the gravel is usually quite angular, and the deposits are from a few inches to several feet in thickness. In the third class gravel is of course absent, the washable ground consisting of the upper decomposed layer in place, the gold being derived directly from the partially disintegrated quartz-veins.

5. MINOR BELTS IN NORTH CAROLINA.

On the west side of the Blue Ridge, in Henderson county, N. C., gold has been mined at the Boylston mine. The country rocks are fine-grained mica- and hornblende-schists, in part much crumpled. The general strike is N. 20°–30° E., and the dip is N.W. The schists are cut by a granite dike. The valley of Boylston creek is made up of schistose limestone, underlying these crumpled schists. These rocks are probably to be classed in the Ocoee, which by some is supposed to be Algonkian and by others Paleozoic, and by others still, it is believed to contain formations of different ages ranging between these two. This isolated belt, however, has little economic importance in connection with gold deposits.

Another belt of auriferous rocks is that in which some unimportant placer-mining operations have been prosecuted in Swain, Jackson, Macon, Clay, and Cherokee counties, N. C. The country-rock is supposed to be largely Ocoee. In Tennessee the petty stream deposits of

Polk, McMinn, Monroe and Blount counties are probably in the same horizon.

6. THE GEORGIA BELT.

The Georgia belt is probably of next or equal economic importance to the Carolina belt. Beginning in Rabun and Habersham counties, in the northeastern corner of the State, it extends in a southwesterly direction through the important mining town of Dahlonega, and thence to the Alabama line in the vicinity of Tallapoosa. This is in the Piedmont region of the State, lying on the southeast side of the Blue Ridge. Although the maximum width (N.W. and S.E.) over which the mines are distributed is as great as 30 miles, the principal portion of the belt, which extends from near Canton, in Cherokee county, through Dahlonega and Nacoochee, to Clayton, in Rabun county, is concentrated in a width of 4 miles or less. It is to this latter portion that the following geological descriptions more especially relate.

THE COUNTRY-ROCKS.

The rocks of this belt resemble in many respects those already described under the South mountain belt in North Carolina. They are Archæan micaceous and hornblendic gneisses and schists, which probably represent sheared granitic and dioritic rocks. At the Murray mill, on Yahoola creek, near Dahlonega, a large mass of unsheared granite may be seen; and massive granite is reported to exist on Yonah Peak, near Nacoochee. These gneisses and schists are banded in narrow, lenticular-shaped layers, from 2 to 20 feet wide. A dark-colored, schistose hornblende rock, locally known as "brick-bat," is of frequent occurrence. Its structural relations are very difficult to determine; at times it is conformably interlaminated with the other schists (as at the Hedwig mine, near Auraria); again, it appears to have no regular relation in its position to the adjoining schists, which are cut off by it or very markedly disturbed in their strike, bending around the "brick-bat" mass, and developing a crumpled or folded structure in the schistose laminæ (as at the Singleton and Lockhart mines, near Dahlonega). It is possible that these "brick-bat" masses, which appear to be dioritic in origin, are magmatic segregations or blebs, similar to the pyroxenic and hornblendic blebs described in the South Mountain region,[1] though, as a rule, larger. The prevailing strike of the gneisses and schists is N. 20°–30° E., and the dip 30°–60° S.E. Locally, however, in the presence of the dioritic masses, as explained above, this changes to northwest strikes with northeast dips. The rocks are often garnetiferous and contain rarer accessory minerals, such as monazite,[2] though

[1] See page 18, above, and Bull. 3, *North Carolina Geological Survey*, 1896, p. 157.

[2] At the Glades Post-Office, in Hall county, 10 miles northeast of Gainesville, monazite has been found in some quantity.

to a much lesser degree than in the South mountain rocks. The depth of the saprolites in the Georgia belt reaches a maximum of about 100 feet.

Diabase dikes, such as are common in the Carolina belt, are not found in the Georgia belt. Granitic dikes are, however, not uncommon in the Nacoochee region.

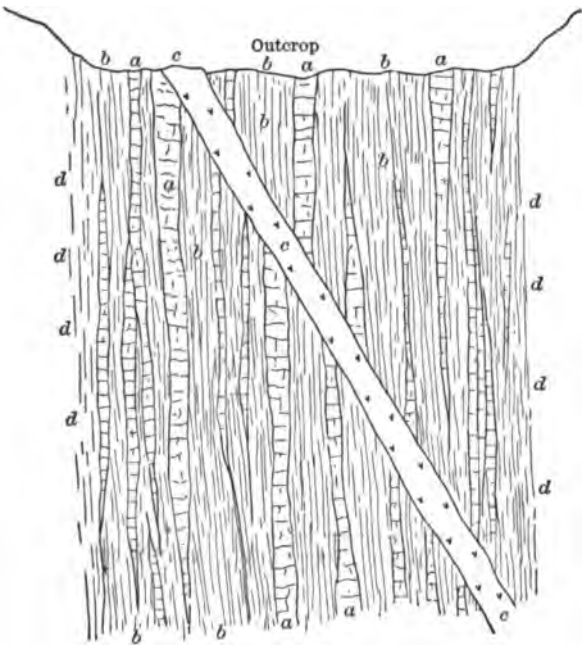

Fig. 2.—Cross-section in Opening at Thompson mine, near Nacoochee, Ga. Scale, 1 inch=2 feet. *a*, quartz; *b*, slate; *c*, granite dike; *d*, wall rock.

The accompanying sketch (fig. 2) represents a small pegmatite dike at the Thompson mine, 4 miles west of Nacoochee, showing the development of normal faulting. Similar granitic dikes have been found in Cherokee county, near the Franklin mine. In the Dahlonega district, although no unquestionable well-marked dikes are seen in place, Mr. Becker[1] calls attention to the possibility that some of the unusually sharply marked sheets in the gneiss might be intrusive.

THE ORE DEPOSITS.

Certain bands of the gneisses and schists have been fissured and filled with gold-bearing quartz and sulphurets. These fissures are in the

[1] "Reconnoissance of the Gold Fields of the Southern Appalachians," *Sixteenth Annual Report of the U. S. Geological Survey*, 1894-5, part iii, p. 296.

main parallel to the schistosity of the rock, though not uncommonly they cut the same at low angles. To a large extent they are aggregated in a zone of numerous narrow and discontinuous lenses and stringers through more or less definite bands of the gneiss, which, taken altogether, form the vein. This is well illustrated in Fig. 2. Mr. Becker has designated such a system, a "stringer-lead."[1] In these narrow, sharply-banded gneisses and schists of different material, such as they are in this part of the Georgia belt, it is natural that the fracturing force, once exerted in a certain band, should have been more or less confined to this one, both longitudinally and transversely, the walls of the band forming the walls of the ore-body. This is in fact the case. At times the fissuring is confined to the light-colored mica-gneisses, at other times to the dark-colored ferromagnesian gneisses and schists. The "brick-bat" schists rarely contain ore-bodies. The thickness of the veins is from less than 3 to as much as 20 feet; they are frequently close together, separated by non-auriferous bands of gneiss; and the total width of the ore-bearing ground reaches as much as 200 feet (Singleton mine, Dahlonega). The extent of fissuring must depend largely on the degree of homogeneity of the material, as well as on the intensity of the fracturing force. Where the rock is of homogeneous composition and the force uniformly exerted, the effect would be a more or less evenly distributed shattering, with few gaping fissures, and the whole mass would be permeated by the gold-bearing solutions, with the formation of auriferous and pyritic impregnations, with some small quartz-stringers. At the Hedwig mine, near Auraria, for instance, regular quartz masses of any size are altogether absent, the ore-body being composed of soft, sandy, mica-gneisses and -schists containing only a few, small and isolated quartz-stringers. Again, under different conditions, the effect was the production of a large number of small open fissures, inducing the consequent formation of numerous small lenticular quartz-stringers; and such is the usual case in the Dahlonega ore-bodies (fig. 2, p. 22). Or, where the rock mass was of still greater heterogeneity, and the forces of greater or more varied intensity, lenticular fissures have been opened, of such size and extent as to allow a more or less complete filling by solid auriferous and pyritic quartz, from 3 to 14 feet in thickness; while, further along the strike, though the fracturing extends to the same width and the walls hold out, the intervening space of country has simply been shattered, or opened only in small spaces, but was nevertheless filled with pyritic impregnations and quartz-stringers, (as at the Franklin mine in Cherokee county, where these barren portions of the vein are called horses). But the

[1] "Reconnoissance of the Gold Fields of the Southern Appalachians," *Sixteenth Annual Report of the U. S. Geological Survey*, 1894-5, part iii, p. 283.

leads are continuous, usually for considerable distances. At the Lockhart mine, near Dahlonega, for instance, the Blackmore vein, 3 to 6 feet in thickness, has been opened by a drift 400 feet long. At the Franklin mine, in Cherokee county, the ore-body has been explored by underground workings for 1000 feet, and the continuity of the vein has been traced for three-quarters of a mile by isolated shafts. The regularity of the vein structure at the Franklin is exhibited by well-defined walls, and by the presence of a soft "gouge" on both the foot and hanging, even where there is no marked quartz filling.

Small, clean-cut cross-fissures occur in the Georgia belt, as at the Franklin mine, where the filling is chiefly calcite.

The pitch of the ore-bodies in the Georgia belt is as a rule to the northeast. The filling of the fissures is quartz, carrying pyrite and rarely chalcopyrite. Among the most interesting gangue minerals may be mentioned garnets, which in cases have been found to be auriferous.[1] Another occasional, though rare, gangue mineral is tourmaline. Gold in close association with a tellurium mineral has been found in the so-called "Boly Fields" vein on the banks of the Chestatee river.[2] The character of the quartz varies greatly, from very saccharoidal to extremely vitreous types, and from clear transparent to milky-white in color, sometimes smoky.

The genesis of the ore deposits is best explained by the ascension theory; there is no evidence of substitution. The formation of the ore deposits was subsequent to the force that sheared the country-rock, from the fact that fragments of the schistose country occur in the quartz.

The character of the gravel placer deposits in the Georgia belt is similar to that in the South Mountain belt.

THE CAROLINA BELT IN GEORGIA.

Mention has already been made (p. 15) of the extension of the Carolina belt into Wilkes, McDuffie and adjacent counties, Georgia.

MINOR BELTS IN GEORGIA.

The crystalline rocks of Georgia are comprised in the large area lying north of a straight line drawn from Augusta to Columbus. Within this area there are, besides the principal gold-ore belts mentioned above, a large number of minor belts; in fact, almost every county in the region claims some discovery of the precious metal. Among the more important are a belt including portions of Gwinnett, Milton, DeKalb, Fulton, Campbell, Fayette, Coweta, Meriwether and Troup counties; and a

[1] "Reconnoissance of the Gold Fields of the Southern Appalachians," *Sixteenth Annual Report of the U. S. Geological Survey*, 1894-5, part iii, pp. 279, 297.

[2] See paper by Dr. Wm. P. Blake, *Trans. Am. Inst. Min. Eng.*, Vol. xxv, 1896, p. 802.

small belt lying on the northwest side of the main Blue Ridge divide, in Towns, Union and Fannin counties, extending into Clay county, N. C.

7. THE ALABAMA BELT.

The Alabama belt might be considered a continuation of the Georgia belt. However, principally as a matter of convenience for reference, it is spoken of and described separately here. It comprises an area of about 3500 square miles, situated in the crystalline rocks of Cleburne, Randolph, Talladega, Clay, Tallapoosa, Chambers, Coosa, Elmore and Chilton counties. This is the southwest extremity of the southern Appalachian gold field.

On the latest geological map of Alabama,[1] the gold-bearing rocks of this area are distinguished as: 1. The semi-crystalline Talladega shales of Algonkian age, including argillaceous and hard, greenish, sandy shales (often graphitic); 2. The crystalline schists of Archæan age, including mica-schists, which, on the one hand, grade through gneisses into granite, and, on the other, into siliceous schists; garnetiferous hornblende-schists, probably of dioritic origin, also occur. The general strike is N.E. and the dip S.E.

The quartz-veins are interlaminated in these rocks, coinciding imperfectly with the dip and strike of the schistosity. From a structural geological standpoint, the veins bear much similarity to those of the Dahlonega type. From a mining standpoint, however, they are different, not forming the wide belts of numerous parallel leads, as in Dahlonega. The quartz is usually glassy; the sulphurets are in the main pyritic, and the gangue minerals are those of usual occurrence in gold-bearing quartz-veins elsewhere. The character of the placer deposits presents no novel features.

[1] Geological Map of Alabama, with Explanatory Chart, *Geological Survey of Alabama*, 1894.

CHAPTER II.

HISTORICAL NOTES: MINING, METALLURGICAL AND STATISTICAL.[1]

EARLY DISCOVERIES OF GOLD IN THE SOUTH APPALACHIAN REGION.

For an account of probably the earliest discoveries of gold in the southern part of what is now the United States by the Spanish explorers we refer the reader to Mr. G. F. Becker's paper, *Reconnoissance of the Gold Fields of the Southern Appalachians.*[2]

Reports of the existence of gold in the Southern States antedate the time of the Revolutionary war, as for instance, in South Carolina at the Brewer mine in Chesterfield county, and in North Carolina at the Oliver mine in Gaston county, the Dunn mine in Mecklenburg county, and the Parker mine in Cherokee county.

However, no absolutely authentic references to these can be obtained, and the date of the first actual discovery of gold in this country must remain shrouded in uncertainty.

Jefferson, in his *Notes on Virginia* (1782), mentions the discovery of a nugget containing 17 dwts. of gold four miles below the falls of the Rappahannock river. The U. S. Mint reports give the first returns from Virginia in 1829. For North Carolina the first mint returns appear in 1793; but the first mention of any specific find of gold in North Carolina is of a 17-pound nugget, discovered on the Reed plantation in Cabarrus county, in 1799.

Mills, in his *Statistics of South Carolina*, notes the occurrence of gold in Abbeville and Spartanburg districts as early as 1826, but the first U. S. mint returns from this State are given in 1829.

The gold placers in Burke and McDowell counties, North Carolina, (South Mountain belt) were first worked in 1829, and immediately traced southwestward through South Carolina into Georgia.

John Witheroods, of North Carolina, claims to have first discovered gold in Georgia in 1829 at Duke's creek, near Nacoochee, Habersham county;[3] but Jesse Hogan, also of North Carolina, claims to have taken

[1] We are indebted to Mr. Geo. R. Hanna, of the Charlotte Assay office, for valuable notes relating to the History of Mining and Metallurgical Operations in North Carolina.

[2] *Sixteenth Annual Report of the U. S. Geological Survey*, part iii, 1894-5.

[3] Now in White county, which was later formed from a part of Habersham.

out gold previously in a branch of Ward's creek near Dahlonega, which was then in the "Cherokee Nation." The earliest mint returns from Georgia appear in 1830.

Dr. Wm. B. Phillips[1] gives 1830 as the probable approximate date of the first discovery of gold in Alabama. There were, however, no mint returns from this State until 1840.

Perhaps one of the chief reasons that the discovery of gold came so much later in Georgia and Alabama than it did in North Carolina and Virginia, was that this part of the country was then occupied by the Cherokee Indian Nation, under the supervision of the United States, and was not open to white settlers, although the latter repeatedly intruded.

After the discovery of gold, the long pending efforts of the States to acquire these Indian lands were stimulated and accelerated by the added thirst for the precious metal, and were finally successful in 1830, when the State laws were extended over the Nation and the Indians were removed. The mining region in Georgia was surveyed into 40-acre lots, which were distributed by lottery. A caustic writer of the time says that, "intrusive mining ceased then and there, and swindling mining commenced."

The first mention of gold in Tennessee is from Coco creek, Monroe county, in 1831,[2] and this date corresponds with that of the first mint receipts.

The earliest record of gold in Maryland is in 1849,[3] from the farm of Mr. Samuel Ellicott in Montgomery county, about 12 miles north of Washington, where a depth of 50 feet was said to have been reached, and about $3000 in gold to have been taken out. The mint reports, however, show no returns previous to 1868.

EARLY MINING OPERATIONS.

The greatest activity of gold mining in the South seems to have followed closely on the first discovery, being most marked from 1829 to 1836, and probably due to the working of the more accessible virgin placers and more easily mined outcrops. The mint receipts show a renewed activity from 1839 to 1849, caused perhaps by more systematic vein explorations and improved methods. In the early fifties, the Californian discoveries abated the interest in the Southern gold field, and attracted the mining population westward, causing a natural depression in the output; from that time on there was a general decrease until the

[1] *Geological Survey of Ala.*, Bull. No. 3, 1892, p. 10.

[2] Safford's *Geology of Tenn.*, 1869, p. 490.

[3] Emmons, E., *Proceedings of the American Philosophical Society*, 1849, Vol. v., p. 85; see also *Am. Jour. Sci.*, Vol. xvii, 1830, p. 202.

practically total cessation caused by the Civil War. Since then there have been spasmodic revivals and depressions, due undoubtedly in a great measure to local causes and excitements, and to the financial condition of the country at large. Considering the small total output of the South, such fluctuations may have been caused by the successful working of a single mine, shown for instance, by the increased production of South Carolina since 1890, owing to the revival of the Haile mine.

The first practical, systematic mining operations appear to have been in North Carolina, beginning about the year 1800. From 1804 to 1827 (inclusive) this State furnished all of the gold produced in the country, amounting to $110,000. The progress up to 1820 was very slow, and mining was restricted to a very limited area. Prof. Olmstead, the first State Geologist of North Carolina, in his writings,[1] estimated the extent of the then known gold country at 1000 square miles. He says: "The gold country is spread over a space of not less than 1000 square miles. With a map of North Carolina, one may easily trace its boundaries, so far as they have been hitherto observed. From a point taken eight miles west by south of the mouth of the Uwharie, with a radius of eighteen miles, describe a circle; it will include the greatest part of the county of Montgomery, the northern part of Anson, the northeastern corner of Mecklenburg, Cabarrus—a little beyond Concord on the west—and a corner of Rowan, and of Randolph. In almost every part of this region gold may be found in greater or less abundance at or near the surface of the ground. Its true bed, however, is a thin stratum of gravel enclosed in a dense mud, usually of a pale blue, but sometimes of a yellowish color. . . . Rocky river and its small tributaries, which cut through this stratum, have hitherto proved the most fruitful localities of the precious metals."

In 1820 articles began to appear in the public journals calling attention to the North Carolina gold deposits, and itinerant German miners and mineralogists had already come into the country in some number.

In 1821, when Olmstead wrote, there was a considerable mining population, whose average earnings were from 60 to 65 cents per day (approximately 65 to 70 cents in the present standard of gold coinage). The toll paid to the owners of the land varied from one-fourth to occasionally one-half of the yield. The dust came to be quite a medium of circulation, and miners were accustomed to carry about with them quills filled with gold, and a pair of small hand-scales, on which they weighed out gold at regular rates, (for instance, 3½ grains of gold was the customary equivalent of a pint of whiskey). The gold found its way largely

[1] *Am. Jour. Sci.*, 1825.

into the country stores in exchange for merchandise at the rate of 90 to 91 cents per pennyweight (96 to 97 cents present standard).

In these early days farming and gold digging went, in many cases, hand in hand; and this is indeed still true, to some extent, at the present day. When the crops were laid by, the slaves and farm hands were turned into the creek-bottoms, thus utilizing their time during the dull seasons. Where mining proved more profitable than planting, the former superseded the latter entirely. Thus, in speaking of the Tinder Flats placer in Louisa county, Va., Silliman says:[1]

"Jenkins is in the habit of substituting a fall working in the gold, for which he obtains $1000 annually, as a compensation for his tobacco crop, which he relinquishes in favor of the gold."

Some of the more prominent localities developed into regular mining camps, where continuous and extensive operations were carried on. Such were, for instance, Arbacoochee and Goldville, Ala.; Auraria and Dahlonega, Ga.; and Gold Hill and Brindletown, N. C. In the latter place it is stated that just before the California excitement as many as 3000 hands might have been seen at work on one of the streams of the region.[2] In 1853 there was a population of about 2000 in the Gold Hill camp.

When Lumpkin county, Ga., was organized in 1832, Dahlonega (then called New Mexico) had a population of 800. During the mining boom Dahlonega had a population of 5000, and Auraria (then called Knucklesville) 2000 to 3000.[3]

At Goldville, Ala., between 1840 and 1850, there was a population of at least 3000.

The first work, naturally, was the washing of the stream placers. After these were exhausted, attention was turned to the gravel deposits lying under cover of the alluvium. These were worked by sinking pits, and raising the gravel by hand labor. Where it was necessary the pits were drained by large vertical bucket-wheels, for which the power was derived from the stream directly, or by flume lines with over-shot or under-shot wheels.

EARLY MINING AND METALLURGICAL METHODS.

The first primitive washing, as in other newly discovered gold countries, was probably done with the pan. As the workings grew more extensive, this was superseded by the rocker, long tom and sluice-box; and, indeed, these original devices survive to the present day.

[1] *Report to the President and Directors of the Walton Mining Company.* By Prof. B. Silliman, Jr., Fredericksburg, Va., 1836.

[2] *Ores of North Carolina*, 1887, p. 312.

[3] Recollections of A. G. Wimpy (a very old citizen of Dahlonega, Ga.) published in the Dahlonega *Signal*, Aug. 20, 1883.

The rockers in use to-day are of two types. The first is essentially a panning process, using a minimum amount of water, the operation being an intermittent one. This type of rocker is closed at both ends, the discharge being over the side; it will be described, with illustrations, as now in use at the Crawford mine (p. 94). The second type consists of a hollow segment of a log closed at the upper end. It is set on a slight inclination, about 6 inches in 10 feet, and is provided at the lower end with grooves or strips that act as mercury pockets or riffles. When used on gravel it is provided at the upper end with a shallow box having a round punched or slotted iron bottom. The length of this type of rocker is 5 to 10 feet. The gravel and clay are thrown into the box, where a constant stream of water, together with the rocking motion and stirring with fork or shovel, disintegrates the material. The pebbles and bowlders are thrown out with the fork, while the fine portions are washed down the bottom. The rocking facilitates the settling and amalgamation of the gold and the discharge of the tailings. Two men work at one rocker or set of rockers, so joined together as to move in harmony. One throws the gravel from the pit into the box, or directly into the rockers, and the other sits or stands above the rockers moving them with his feet, disintegrating the gravel with a fork and discharging the coarse material. Rockers of a similar type are at present in use at several mills for handling pulp and blanket washings. (See Plate I.)

Where sufficient flowing water is at hand, the sluice box and long tom are used, as they handle larger quantities with less labor. The sluice box, generally 8 to 10 feet long, 20 inches wide and 12 inches deep, provided with riffles and a perforated charging plate at the head, fulfils the same purpose as the rocker; being stationary, however, it requires a larger amount of water to carry off the tailings.

It is interesting to note that at the Beaver Dam mine, in Montgomery county, N. C., a large rocker, about 10 feet long by 3 feet wide, was operated as early as 1825 by steam power, the engine having been imported from England.

Tuomey,[1] in 1854, mentions ground-sluicing of side-hill deposits at Arbacoochee, Ala., by aid of a ditch and a series of trenches into which quicksilver was poured. It is probable that this method of working existed even prior to that day.

HYDRAULIC METHODS.

The first use of the hydraulic method of mining was probably early in the forties, previous to the California gold discoveries, in the western part of North Carolina, although on a much smaller and modified

[1] *Second Biennial Report on the Geology of Alabama*, p. 70, Montgomery, 1858.

LOG ROCKERS, GOLD HILL, N. C.

A small stream of water pours from the crude V-shaped trough above into the upper end of each of the larger troughs below, and washes the gravel and soil out at their lower ends.

(See also p. 60.)

CHILIAN DRAG-MILL AND ROCKERS, NEAR GOLD HILL, N. C.

(See page 33.)

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scale as compared to its present application. Mr. Wm. H. Ellet, writing in the *Mining and Statistic Magazine*[1] early in 1858, in reply to Hon. T. L. Clingman's inquiry of December, 1857, says:

"I avail myself of my earliest leisure to answer your inquiries in relation to the hydraulic gold-mining operations lately introduced by Dr. M. H. Vandyke, in some of the western counties of North Carolina. . . . . My observations in the hydraulic process were made during the month of April[2] at the Jamestown mine,[3] in McDowell county, N. C. The water was there conveyed . . . . about 4 miles. The uniform descent was 4 inches to the hundred feet. . . . . The number of hose pipes employed was four. The mass of earth moved in nine working days was 20 feet in depth, 82 in length and 26 in breadth, being at the rate of 1184 cubic feet, or 966 bushels, per day for each hose. . . . . The labor employed . . . . was that of four men and two boys. . . . . The yield in gold was $5.13 per day for each hose employed.

Shortly afterwards a further publication appeared in the same magazine,[4] from which the following extracts are taken:

"The Wilkinson gold mine in Burke county, N. C., is owned by Dr. Van Dyke, and is worked by the hydraulic process. The water is brought . . . . by a canal or aqueduct for a distance of 15 miles. . . . . The water is not brought upon these mines at a very high head, only about 40 feet. There was only one pipe in operation at the time of my visit. The water passed through a 6-inch hose and a nozzle of 1½ inches. . . . . The average yield of the mine . . . . was about $5.00 a day to each hand. . . . . Obtaining a sample of the gold of this mine, we passed over about 2 miles to the Bunker Hill mine, also in Burke county. This was formerly known as the Brindleton mine. It is owned and worked by Rev. Benjamin Hamilton. . . . . It is now worked by the hydraulic process. . . . . The amount of water is limited, sufficient only for about two pipes, which is brought in a small ditch for a distance of 4 or 5 miles. . . . . The Collins mine in Rutherford county is owned and worked by Dr. Van Dyke. The water is brought to this mine in a canal about 4 miles in length, at an elevation of 150 feet, and sufficient in amount for 20 pipes, and will command nearly 1000 acres of surface. . . . . Jamestown mine, McDowell county, N. C., [is] also worked by Dr. Van Dyke. The deposit workings embrace about 400 acres. The water is brought by a canal at an elevation of 70 feet, and is five miles in length. There is water enough here for 20 hose pipes."

Prof. Wm. P. Blake (in 1858) in a "Report upon the Gold Placers of Lumpkin county, Georgia, and the Practicability of Working them by the Hydraulic Method, with Water from the Chestatee River,"[5] says:

"Desiring to see the results obtained [by Dr. M. H. Van Dyke] in North Carolina, and thus to be enabled to form a better judgment of the probable results in Georgia, I first visited the placers in Burke and McDowell counties

[1] Vol. x, pp. 27-30, January 1858. Our attention was called to this and related articles by the interesting paper of Prof. Wm. P. Blake, published in the *Transactions of the American Institute of Mining Engineers*, October 1895, entitled *Notes and Recollections Concerning the Mineral Resources of Northern Georgia and Western North Carolina.*

[2] 1857.

[3] Afterwards and at present known as the Vein Mountain mine.

[4] Vol. x, pp. 393, 394, May, 1858.

[5] *Mining and Statistic Magazine*, vol. x, pp. 457-476, June, 1858.

where the [hydraulic] process is now in successful operation. . . . . The average yield, as shown by the results at several of the North Carolina placers, is about $6.00 a day to a pipe attended by two men, or by a man and a boy. At some of the placers the average is not less than $10.00 a day. . . . . At Brindletown, in the bed of a little brook which has a rapid descent, Mr. Hamilton has been washing very successfully with two pipes and five men and boys. . . . . I am confident that the yield cannot be less than $20.00 a day, even among the former excavations where the gravel has been washed over more than once before."

Lieber[1] mentions the hydraulic process as being practiced previous to 1859 at Pilot mountain in Burke County, N. C., and he evidently has reference to the above described localities.

The Dahlonega method (a combination of hydraulicking, sluicing and milling) originated in 1868.

The first record that we have of *dredge mining* is that carried on by a Mr. Gibson in 1843-4, in the Catawba river, Gaston county, N. C. The river sediments and gravel were scooped out on flatboats by men using long-handled scoops, and the material was carried ashore and washed.

Later on mechanical dredges of various designs came into use, chiefly on the Chestatee river, in Georgia.

The advent of the *hydraulic gravel elevator* dates from about 1883. It was first applied at Brindletown, N. C., and at Dahlonega, Ga. The well-known type of this mechanism, known as the Hendy lift, was employed at the Cincinnati Consolidated Company's mines in Dawson county, Ga., in 1883. The plan was to divert the Etowah river and to suck up the gravel from the old channel.

The Roy Stone method[2] was experimented with in the Chestatee river in 1883, but the results are not known.

The Crandall hydraulic elevator,[3] as used at the Chestatee mine, Georgia, in 1895, contains important improvements over other types of similar mechanisms.

VEIN MINING. FREE-MILLING ORES.

Vein mining probably followed more or less closely on the exhaustion of the richer gravel deposits. The first account of vein mining is in 1825, at the Barringer mine, Stanly[4] county, N. C. In Virginia the veins of the Tellurium and Vaucluse mines were discovered in 1832; and in Georgia the Reynolds vein, lot No. 10, near Nacoochee, in White county, was discovered some time prior to 1834.

[1] *Supplementary Report to the Survey of South Carolina*, 1859, p. 154.
[2] *Trans. Amer. Inst. Min. Eng.*, vol. viii, p. 254.
[3] *Ibid.*, vol. xxvi, 1897, pp. 62-68.
[4] This part of Stanly was then a part of Montgomery county.

EARLY MILLING APPLIANCES.

For a long time the output was confined to the free-milling brown ores near the surface, and the ore was raised by horse-whim and hand-windlass, or even by baskets carried upon the backs of the miners. At first the gold from the ores of the decomposed outcrops of the veins was extracted by washing in rockers. The following quotation from Prof. Elisha Mitchell's *Report on the Geology of North Carolina* (1827), is pertinent here:

"The quartz is raised from the mine, broken to pieces, and those parts which are known to contain gold selected for washing. This part of the process is conducted in the same way as in Montgomery (county), except that the agitation is continued for a longer time, and that a small quantity of quicksilver is put into the rockers to collect the gold, by forming an amalgam with it."

The most primitive method of milling the quartz was undoubtedly by crushing in *hand-mortars* and subsequent panning. This is still carried on by the native tributors in certain districts. It was followed by the introduction of the *drag mill* (*arrastra*), the *Chilean mill* (Plate I, p. 30) and eventually the stamp-mill. The two former were evidently drawn from South American and Mexican practice, and were probably the first mechanical pulverizing machinery used.

As an illustration of some of the earlier milling methods, the following is taken from a report of the Supervising Committee of the United States Mining Company in 1835, on their mine near the Rappahannock river, Virginia:

"The plant consists of a crushing (rolls) and a vertical mill (stamping-mill) in a building 26 × 36 feet. Both mills are located on the ground floor and are propelled by a water-wheel 11 feet in diameter, with a 11-foot face. The crushing-mill has 3 sets of cylinders 2 feet in length and 15 inches in diameter, the first or upper set fluted, the other smooth. The ore is thrown into a hopper on the upper floor, from which it is conducted over an inclined shaking-table to the fluted cylinders, by which it is crushed to a size from ¼ to 1 inch in diameter. The crushed material is equally divided and goes to the two sets of smooth cylinders. By them it is further greatly reduced, ranging from impalpable powder to grains as large as coarse hominy. From these cylinders it falls into a sifter having the fineness and motion of the common meal-sifter, from whence the material which passes through is conducted to 12 amalgamators, constructed upon the principle of the Tyrolese bowls, making from 90 to 100 revolutions per minute. They perform the office of washing and amalgamating. The sand discarded by them, after being washed, is conducted through troughs to the vertical mill, where, being reduced to an impalpable powder, it passes in the shape of turbid or muddy water to another set of amalgamators similar to those above mentioned, and thence to the river. The portion of the ore reduced by the cylinders which passes over the sifters is conducted to the vertical mill, and is treated in the same manner."

The process at another Virginia mine, the Vaucluse, is described[1] in 1847 as follows:

"The machinery consists of a condensing Cornish mining engine of 120 horse-power; the mill-house contains 6 large Chilean mills; the cast-iron bed-plate of each is 5 feet 6 inches in diameter, and on it are two cast-iron runners of the same diameter, the total weight of the mill being 6200 pounds. The ores, on arriving at the surface, are divided into two classes: 1. The coarse and hard ore for the stamps; 2. Slate and fine ore for the Chilean mills. This is done by means of a large screen. The very large pieces are first broken by a hammer before they are fed to the stamps. All of the ores are ground with water, each mill being supplied with hot and cold water at pleasure. Twelve inches from the top of the bed-plate there is a wide, open mouth, from which the turbid water escapes to tanks. On the south side of the steam-engine is the stamp house and amalgamation mill, containing 6 batteries of 3 stamps each; these stamps, with the iron head of 125 pounds, weigh 350 to 380 pounds each. Each battery is supplied with water, and at each blow of the stamp a portion of the fine ore passes out of the boxes through the grates to the amalgamation room. Here are stationed 18 small amalgamation bowls of cast iron, 30 inches in diameter. The bowls are supplied with runners which move horizontally; in the center of these runners is an eye or opening like that in the runner of a corn-mill. The ground or finely-stamped ore, gold and water pass into this eye, and by the rotary motion of the same are brought into contact with the quicksilver deposited in the center, forming amalgam. From the amalgamators the pulp passes through 3 dolly-tubs or catch-alls, acting as mercury and gold tubs. After this the whole mass passes to the strakes or inclined planes, where the sulphurets are deposited and the earthy matter washed away. These sulphurets were formerly treated in two heavy Mexican drags or arrastras; but not answering so good a purpose, they have been altered into three heavy Chilean mills."

The collection of amalgam, retorting and melting was practically the same as to-day. The total plant at this mine was valued at $70,000.

Emmons gives the method of working the ores of Gold Hill, N. C., in the earlier days as follows:[2]

"The machinery employed at Gold Hill for separating gold, consists, first of the Chilean mill for crushing and grinding, after being broken by hammers, the Tyrolese bowls, the Burke rockers, and the drag-mill. . . . . The work for a Chilean mill of this ore is 70 bushels per day, and our mills run for 24 hours, with one or two short interruptions. They are all moved by steam-power, and all the water used in the mills is pumped from the mine. The Burke rocker is the principal and best saving machine employed. The drag-mill is also a good machine, is cheap, and easily kept in repair. On inspecting these operations when going on it is impossible to resist the conclusion that much of the gold is wasted along with the mercury."

Emmons further states the force employed at Gold Hill at that time for working the Earnhardt (Randolph) vein to consist of:

"66 miners paid by the month and 39 negroes hired by the year. The day of 24 hours is divided into three shifts of eight hours each for underground work."

[1] *Plan and Description of the Vaucluse Mine, Orange County, Va.* Philadelphia, 1847.
[2] *Geological Report of the Midland Counties of North Carolina*, 1856. E. Emmons. pp. 160 *et seq.*

The *stamp-mill*, or, as it was originally called, the "pounding mill," was most probably a European innovation. As early as 1836 a 6-stamp mill, with 50-pound stamps, was in operation at the Tellurium mine in Virginia. In 1837 a Frenchman erected a mill at the Haile mine in South Carolina. These primitive mills were constructed of wood, with iron shoes and die-plates; the general type of construction was similar to that of the present California mills, with the exception that the stems were square and did not revolve, the cams working in slots or recesses cut into the stems. A few of these old-fashioned mills may still be seen in operation in Georgia in the Nacoochee valley, seemingly serving the purpose of the tributors and petty quartz miners, and it is stated that they are operated at a fair profit. They are cheaply constructed, a 10-stamp mill with water-wheel and building complete costing about $150. The amalgamation is done on a copper plate of the width of the battery and about one foot long.

The first regular California battery was erected at the Kings mountain mine, in North Carolina, just after the war; and in 1866 a similar mill was built at the Singleton mine, in Georgia, by Dr. Hamilton.

Besides mills of Western manufacture, there are two types which are common to the South. One of these is an excellent 750-pound mill built by the Mecklenburg Iron Works of Charlotte, N. C., a slight variation of the Western type (described on p. 119). The other is the 450-pound Hall mill, which is peculiarly adapted to the saprolitic ores of the Dahlonega district in Georgia (described on pp. 110–113.)

Various types of *rotary pulverizers* and *pan amalgamators* have been introduced in the South from time to time, supposedly as improvements on the stamp-mill, as, for instance, the *Howland mill*, a flat circular disc revolving in an iron shell; and, similarly, the *Crawford* (with revolving iron balls) and the *Huntington mills;* the *Parson mill*, not unlike the Howland, but covered with a hood, and having the interior grinding surfaces coated with lead-amalgam; the *Meech mill*, in which the quicksilver was comminuted by superheated steam; the *Wiswell mill*, being practically an iron Chilean mill fed with corrosive sublimate in connection with an electric current; the *Nobles process*, in which the ore was ground to 100-mesh between buhr-stones and the pulp run over amalgamated slabs of zinc or lead. Revolving *Freiberg barrels* were also used at some of the mines. The *Blake system* of fine crushing, combined with subsequent wet grinding,[1] was introduced at the Haile mine in 1884, but was soon abandoned in favor of the present stamp-mill.

The above are simply cited as a few examples of the vast number of mechanical appliances for grinding and amalgamation with which the

[1] *Trans. Amer. Inst. Mining Engineers*, vol. xvi, p. 755.

mines of the Southern States have been overrun. Although some of these, notably the Huntington mill, are still in use at a few places, it has been quite clearly demonstrated that such grinding apparatus produces float gold and flours the quicksilver, besides which the mechanism is subjected to great strain and wear, against all of which defects the stamp battery, with plate amalgamation, has proven itself vastly superior, and through all of its vicissitudes it has held the field as the most economical and rational apparatus for milling and amalgamating gold ores.

TREATMENT OF SULPHURET ORES.

As soon as the water-level was reached in the mines, and the free-milling brown ores were practically exhausted, attempts were made to treat the undecomposed sulphurets.

MECHANICAL METHODS.

Probably the earliest method employed for the concentration of these sulphurets was that used at the Vaucluse mine in 1847 (described on page 34), which consisted in passing the material over strakes or inclined planes. This was probably followed by buddles, primitive bumping-tables and more especially by blankets. Log rockers were also used at an early date for this purpose. At the present day the Frue, Embrey and Triumph concentrators are in general use. Of these, the Embrey machine is considered by some to give better results, especially where skilled labor cannot be obtained, and where the sulphurets are not sized. Still, each one of the three finds its strong advocates, and the difference in perfection of concentration obtained by them is probably not material. In some cases—as, for instance, in the Gold Hill district—the finely-divided condition of the gold has led to the re-employment of blankets.

At the Reimer mine, North Carolina, a plant was in operation in 1883 in which the ore was comminuted in a series of crushers and 26-inch rolls; the pulp was sized into six grades, from 10- to 60-mesh, and each grade treated separately by a Bradford jig. This process is said to have given good results, but the plant was destroyed by fire soon after its erection and never rebuilt. The same system of jigging was at one time in use at the McGinn mine in North Carolina.

The earliest treatment of the concentrated sulphurets was by regrinding them (in the raw, unroasted state) in Mexican arrastras and Chilean mills, with subsequent amalgamation, as described above in the practice of working the ores at the Vaucluse mine, Virginia, in 1847.

In 1852-53, a Dr. Holland, of Massachusetts, introduced a roasting process at some mines near Charlotte, N. C., in which the pyritic con-

centrates were mixed with nitrate of potash or soda and roasted in a reverberatory furnace at a low heat.

Lieber stated[1] in 1856 that a process for roasting sulphurets, with subsequent amalgamation, had been introduced by a Mr. C. Ringel at a mine near Rutherfordton, N. C. (this was probably the Alta mine), and was afterwards practiced with success on old tailings at the Gold Hill and other mines in North Carolina.

In the past history of the Southern mines a vast number of roasting processes and furnaces have been introduced, many of them approaching the ludicrous, but they have never lasted beyond the experimental stage. Heap-roasting with salt was also tried.

Some of the furnaces, particularly of the well-known reverberatory type, were successful enough so far as the roasting went; the fault lay in the prevalent and popular belief that, by oxidizing the sulphurets, the difficulty of amalgamating the precious metals, which had been set free, would be removed, when in fact the resulting coating of iron oxide was nearly as fatal to the work as the sulphide had been.

The Bartlett method of making white lead-zinc oxide was introduced at the Silver Hill mine, North Carolina, in 1871-2. It consisted in roasting the concentrated galena-blende and condensing the zinc-lead oxide fumes, which made a good paint material. The process is said to have been carried on successfully until all the available suitable material was exhausted.

CHEMICAL TREATMENT.

The next step was in the direction of a chemical treatment of these refractory sulphurets. It would be useless to outline the numerous processes that were experimented with for this purpose. The South has been, much to its detriment, the "proving ground" of almost all the patent gold-saving processes invented, and the greater proportion of these have, as might have been predicted, resulted in utter failure. Of all these the chlorination process is practically the only survivor; and there is a possibility of the successful application of the cyanide process.

THE CHLORINATION PROCESS.

It was not until 1879 that the successful treatment of pyritic sulphurets was accomplished by the introduction of the chlorination process. In that year a Mears chlorination plant was erected at the Phoenix mine, North Carolina, under the management of Mr. A. Thies, who soon improved on and developed it into what is now universally known as the Thies process.

[1] *Report on the Survey of South Carolina for* 1856, p. 47.

In 1880 a chlorination plant (the Davis and Tyson Metallurgical Works) was erected two miles south of Salisbury, N. C. The process used was known as the Davis process, which differed from the Mears only in the method of precipitating the gold with charcoal instead of ferrous sulphate. These works were in spasmodic operation on custom ores for several years.

In 1881 a Davis plant was erected at the Reimer mine, North Carolina, but was shortly burned down, before thorough testing.

In 1882 the Plattner chlorination process was introduced at the Tucker mine, North Carolina, but was not successful, and in the following year the Mears process was substituted, which also had a short existence here. These failures were, however, most probably due to the impracticable application of the methods rather than to the character of the methods themselves.

Experiments were made several years ago by Mr. P. G. Lidner at the Brewer mine in South Carolina, and at Dahlonega, Ga., with a chlorination process for treating the ore in bulk; and a plant for a patent electrolytic-chlorination process was erected in 1895 at the Clopton mine, Villa Rica, Ga. None of these have, however, met with practical success.

At the present time the Thies process is in successful use at the Haile mine, South Carolina, and the Franklin and Royal mines, Georgia.

THE CYANIDE PROCESS.

The cyanide process has so far found but little application in the South. In May, 1892, Mr. Richard Eames, of Salisbury, N. C., experimented with cyanide at the Gold Hill mine, N. C., extracting 60 per cent of the assay value. In the summer of 1893, a 10-ton cyanide plant was working at the Moratock mine, N. C., but the operations were soon relinquished here on account of the low grade and character of the ore. Later in the same year, a cyanide plant was in operation at the Gilmer mines in Goochland county, Va.; with what success could not be ascertained. At the Franklin mine, Ga., a treatment of the ores with cyanide was attempted before the introduction of the chlorination process. It proved successful on the oxidized tailings from the old dumps; but the extraction from fresh sulphurets was insufficient to warrant its continuation.

In 1895 cyanide experiments were made at the Sawyer mine, in Randolph county, N. C., but were soon abandoned. In 1896 a 30-ton cyanide plant was erected at the Russell mine, N. C., by the American Cyanide Gold and Silver Recovery Company of Denver, Col., and a small plant was also built at the Cabin Creek (Burns) mine, N. C., by the same company, but neither of these has yet been put in practical operation.

OTHER CHEMICAL PROCESSES.

The *Hunt and Douglas process* was successfully applied in 1880 to the ores of the Conrad Hill mine, N. C. The roasted sulphurets were leached with a ferrous chloride solution, converting the copper to a soluble chloride, from which it was precipitated as metallic cement on scrap iron.

The *Designolle process*, which consisted in treating the roasted ore with corrosive sublimate in iron vessels, was only moderately successful in its application, for the reason that it made a very base bullion, the iron of the apparatus invariably precipitating any soluble salts formed in the roasting. It was worked for a time, during 1882-83, at a custom plant near Charlotte, N. C.; at the New Discovery mine, Rowan county, N. C. (1883), and at the Haile mine,[1] S. C. (1883).

A plant for the extraction of gold from pyritic concentrates, with the recovery of the sulphuric acid, was erected early in the present decade at Blacksburg, S. C., mainly for the treatment of custom ores. The concentrates were roasted in a Walker-Carter muffle furnace, which was connected with lead chambers. The amalgamation of the roasted product was carried on by a patent process known as the *Caloric Reduction Company's process*, the principle of which was a volatilization of mercury into the mass of the pulp, followed by a condensation of the same, the amalgam being led into settling vats. It was proposed to use the tailing residues for the manufacture of red paint. The scheme, as might have been predicted, was a failure. A similar process, known as the *Phelps process*, had already been unsuccessfully tried on North Carolina ores, in (about) 1877, in an experimental plant situated at Philadelphia.

Attempts at *pyritic smelting* were made as early as 1847 at the Vaucluse mine in Virginia by Commodore Stockton, but resulted in failure.

Matte smelting, followed by refining in reverberatory furnaces, was practiced (about 1881-1882) on the copper ores of the Conrad Hill and the North State mines in North Carolina.

Experiments on matting auriferous sulphurets from the Haile mine, S. C., were made in 1886 by Mr. E. G. Spilsbury,[2] but proved unsuccessful.

Regarding smelting processes in the South, probably most has been done in the attempted treatment of the complex galena-blende ores, carrying silver and gold, of the Silver Hill and Silver Valley mines, Davidson county, N. C.

The process in use at Silver Hill, as early as 1853, was heap-roasting, followed by wet-crushing in a stamp battery, the zinc oxide being dis-

[1] *Trans. Amer. Inst. Min. Engs.*, vol. xv, p. 771.
[2] *Trans. Amer. Inst. Min. Engs.*, vol. xv, pp. 767-775.

solved and recovered separately, after which the residues were smelted in the old-fashioned Scotch open-hearth lead furnace, and the precious metals were recovered from the pig lead by refining in a cupellation furnace.[1]

During the past twelve years a number of patent processes have been experimentally tried on the Silver Valley ores in a plant situated at Thomasville, N. C., but it was not until 1895 that a successful process was introduced by Mr. Nininger, of Newark, N. J. It consists of a down-draught jacket furnace, through which the fumes of lead and zinc are carried downward into condensers, where they are met by a spray of water, the liquor being led to vats where the lead oxide is deposited, while the zinc remains in solution and is subsequently precipitated as zinc oxide. The matte, carrying copper, gold and most of the silver, is tapped from the well of the furnace and cast into pigs.

PRODUCTION OF GOLD AND SILVER IN NORTH CAROLINA AND OTHER SOUTHERN STATES.

The following table, compiled from the production reports of the United States Mint, gives an estimate of the gold and silver production of the Southern States down to the present time. The figures represent not only the amounts deposited at the United States Mint and Assay Offices, but also such amounts that were produced and not turned into the mint and of which records could be obtained:

TABLE I.—*Estimate of the Production of Gold and Silver in each of the Southern States from* 1799 *to* 1879 *and Annually Since.*

Year.	Md.	Va.	N. C.	S. C.	Ga.	Ala.	Tenn.	Total.
1799–1879	$2,500	$3,091,700	$19,659,600	$2,587,900	$14,180,500	$365,300	$155,300	$40,042,800
1880...	250	11,500	95,000	15,000	120,000	1,000	1,500	244,250
1881....	500	10,000	115,000	40,000	125,000	1,000	1,750	293,250
1882....	1,000	15,000	215,000	25,000	250,000	3,500	250	509,750
1883....	500	7,000	170,000	57,000	200,000	6,000	750	441,250
1884....	500	2,500	160,500	57,500	137,000	5,000	300	363,300
1885....	2,000	3,500	155,000	43,000	136,000	6,000	300	345,800
1886....	1,000	4,000	178,000	38,000	153,500	4,000	500	379,000
1887...	500	14,000	230,000	50,500	110,500	2,500	500	409,000
1888 ...	3,500	7,500	139,500	39,200	104,500	5,600	1,100	300,900
1889....	3,500	4,113	150,174	47,085	108,069	2,639	750	316,330
1890....	16,962	6,496	126,397	100,294	101,318	2,170	1,001	354,638
1891...	11,264	6,699	101,477	130,149	80,622	2,245	519	332,975
1892....	1,000	5,002	90,196	123,881	95,251	2,419	1,006	318,755
1893....	114	6,190	70,505	127,991	100,375	6,362	250	311,787
1894 ..	978	7,643	52,927	98,763	99,095	4,092	329	263,827
1895...	501	6,325	69,196	128,303	128,403	4,708	335	337,771
1896....	1,037	4,466	52,056	100,711	150,085	6,695	582	315,632
Total..	$47,606	$3,214,234	$21,830,528	$3,810,277	$16,380,218	431,230	$167,022	$45,881,115

In order to give an idea of the fluctuation from 1799 to 1896, Table No. 2 is given. These figures, however, comprise only the actual

[1] *Mining Magazine*, vol. 1, 1853, p. 367 *et seq.*

United States Mint and Assay Office receipts, and do not include such bullion as went abroad, was sold directly to local jewellers, or was coined by the Bechlters[1] at Rutherfordton, N. C.

TABLE II.—*Statement of Gold and Silver produced in all of the Southern States; Deposited at the United States Assay Offices from* 1793 *to* 1896 *inclusive.*

Year.	Amount.	Year.	Amount.	Year.	Amount.
1793-1823	$47,000	1848	$850,692	1873	$158,952
1824	5,000	1849	891,968	1874	141,647
1825	17,000	1850	658,605	1875	150,612
1826	20,000	1851	500,539	1876	138,256
1827	21,000	1852	711,449	1877	159,009
1828	46,000	1853	486,184	1878	162,925
1829	140,000	1854	323,489	1879	186,123
1830	466,000	1855	362,349	1880	203,770
1831	519,000	1856	325,820	1881	197,084
1832	678,000	1857	141,810	1882	229,459
1833	868,000	1858	349,323	1883	272,475
1834	898,000	1859	379,677	1884	255,259
1835	686,300	1860	231,398	1885	239,963
1836	667,000	1861	141,778	1886	272,414
1837	282,000	1862	6,298	1887	390,531
1838[2]	358,750	1863	1,624	1888	234,947
1839	429,648	1864	6,093	1889	224,323
1840	427,311	1865	33,345	1890	269,997
1841	544,661	1866	202,000	1891	254,707
1842	723,761	1867	106,903	1892	262,023
1843	1,050,100	1868	155,660	1893	261,904
1844	928,095	1869	191,738	1894	263,827
1845	986,849	1870	168,057	1895	319,496
1846	992,792	1871	138,791	1896	270,210
1847	1,018,079	1872	164,461		
				Total,	25,870,310

The following note concerning this local coinage by the Bechtlers is added by Mr. Geo. B. Hanna of the U. S. Assay Office at Charlotte, N. C.:

"Gold was coined at Rutherfordton by three Bechtlers: Christian Bechtler, A. Bechtler and Christian Bechtler, Jr. A. Bechtler came in between C. Bechtler and C. Bechtler, Jr. I have in hand a 5-dollar gold piece stamped 'A.'

[1] Christian Bechtler, jeweller by trade, who resided near Rutherfordton, N. C., was urged by residents in Rutherford and adjoining counties to coin the gold of that neighborhood, as transportation to the only mint then existing (Philadelphia, Pa.) was hazardous and difficult. He commenced coining in 1831, and continued until his death, in 1843, when his nephew, C. Bechtler, Jr., continued the minting until 1857. No regular entries of the quantity of gold minted were made; sometimes as much as $4000 to $5000 were coined in a week; and for a period of ten years the annual quantity was fairly equal. See *Second Annual Report Survey of South Carolina*, 1857. O. M. Lieber, p. 135.

[2] The years 1838 to 1847 exclude the amounts deposited at the New Orleans Mint, which were not available for each year. The total amount at New Orleans in those years from the Southern States was only $116,086.

Bechtler, and it is the most artistic of all the 5-dollar coins. C. Bechtler also coined 5-dollar gold pieces stamped 'Georgia Gold'; a very few pieces are stamped 'August 1, 1834,' which date marked a change in the U. S. standard gold coin. The presumption is that all the Bechtler gold coins prior to this date were bought up at a premium, and recoined at a profit of nearly 7 per cent. The denominations coined were $1.00, of quite various patterns, and 2½ and 5-dollar pieces; the dollar pieces ranged from 27 to 30 grains. The coins were generally stamped with the carat, 20 c. being the lowest observed. The character of the stamping varied greatly, that of the dollar pieces being very poor, and these were extensively counterfeited. The alloy was silver and the coin had a pale brassy look. Some coins were specifically stamped 'North Carolina' gold; others merely 'Carolina Gold' or 'Georgia Gold.'"

In Table No. 3 the totals found in Table No. 2, from the years 1880 to 1896, are distributed among the various States.

TABLE III.—*Statement of Gold and Silver Produced in each of the Southern States; Deposited at the United States Mint and Assay Offices from* 1880 *to* 1896 *inclusive.*

	Md.	Va.	N. C.	S. C.	Ga.	Ala.	Tenn.	Total.
1880....	$191	$11,071	$77,405	$10,071	$103,066	$696	$1,270	$203,770
1881....	253	9,147	55,990	23,093	106,548	700	1,353	197,084
1882....	754	13,540	82,473	16,268	114,507	1,690	227	229,459
1883....	310	6,343	100,294	48,428	116,401	147	552	272,475
1884....	...	2,024	88,861	48,511	115,000	740	123	255,259
1885....	1,539	2,954	64,826	39,766	128,148	2,611	119	239,963
1886....	559	2,873	83,400	36,187	146,027	3,051	317	272,414
1887....	199	12,613	216,788	52,142	107,537	1,021	231	390,531
1888....	2,174	6,514	88,641	37,408	97,824	1,478	908	234,947
1889....	558	2,608	81,196	44,923	92,307	2,332	399	224,323
1890....	7,852	2,601	75,192	97,646	85,715	626	365	269,997
1891....	4,244	4,197	53,993	127,161	63,722	1,222	168	254,707
1892....	249	4,473	50,336	120,582	83,616	2,286	481	262,023
1893....	203	4,300	36,454	122,964	92,859	4,895	229	261,904
1894....	978	7,643	52,927	98,763	99,095	4,092	329	263,827
1895....	500	3,674	54,649	128,904	128,487	2,947	335	319,496
1896....	300	3,500	44,946	63,688	151,776	5,700	300	270,210

In the Census Report for 1880, vol. xiii, can be found statistics concerning gold mining in the Southern States tabulated under the following headings: Directory of deep mines; Means of handling water in deep mines; Cost of supplies in deep mines; Directory of ditches; Cost of ditch plants; Grades and dimensions of ditches; Length of water season; Placer directory; Tunnels in placer mines; Stamp batteries; Amalgamating mills; Arrastras; and Roasting furnaces.

CHAPTER III.

DISTRIBUTION OF GOLD MINES IN NORTH CAROLINA, WITH MINING NOTES.[1]

The North Carolina mines are distributed in three main belts—the Eastern Carolina, the Carolina, and the South Mountain belts (see pp. 14, 15–18).

The distribution of gold deposits and geological formations in North Carolina is indicated in a general way by the accompanying map (fig. 3, p. 44); but this is shown in greater detail and accuracy on the larger map which accompanies Bulletin 3 of the Survey reports.

The mining districts of North Carolina have been more extensively developed than those in any other portion of the South; although to-day a comparatively small number of the mines are in operation. Of these, very few can be said to be steady producers, most of the work being prospecting and preliminary development, with irregular and spasmodic output. Petty mining, chiefly in the placer ground, is carried on by tributors in various parts of the State.

THE EASTERN CAROLINA BELT.

The principal mines are situated in Warren, Halifax, Franklin and Nash counties, in an area covering about 300 square miles, and extending in a southwesterly direction from a point near the Thomas mine, 1½ miles northeast of Ransoms bridge, to and across Tar river.

Among the mines in this belt are the Thomas, Kearney, Taylor, Mann, Davis, Nick-Arrington, Mann-Arrington, and Portis. Of these the two latter are, perhaps, of most importance.

The MANN-ARRINGTON mine is situated in the northwest corner of Nash county, at Argo P. O. The country-rock is chlorite-schist, in part porphyritic, striking N. 60° E. and dipping 40° S.E. The ore-body consists of quartz lenses from minute size up to 12 inches in thickness,

[1] For fuller description of some of the mines, the reader is referred to:
Geological Report of the Midland Counties of North Carolina, by Ebenezer Emmons, New York, 1856.
"The Ores of North Carolina," by W. C. Kerr and George B. Hanna, *North Carolina Geological Survey*, 1887.
"The Gold Deposits of North Carolina," by H. B. C. Nitze and G. B. Hanna. *North Carolina Geological Survey*, 1896. Bull. No. 3.
Unless otherwise stated, the mines are not at present working. The values of the ores are not given on our authority; the same is true of the dimensions of the ore bodies in abandoned mines and in such as could not be examined.

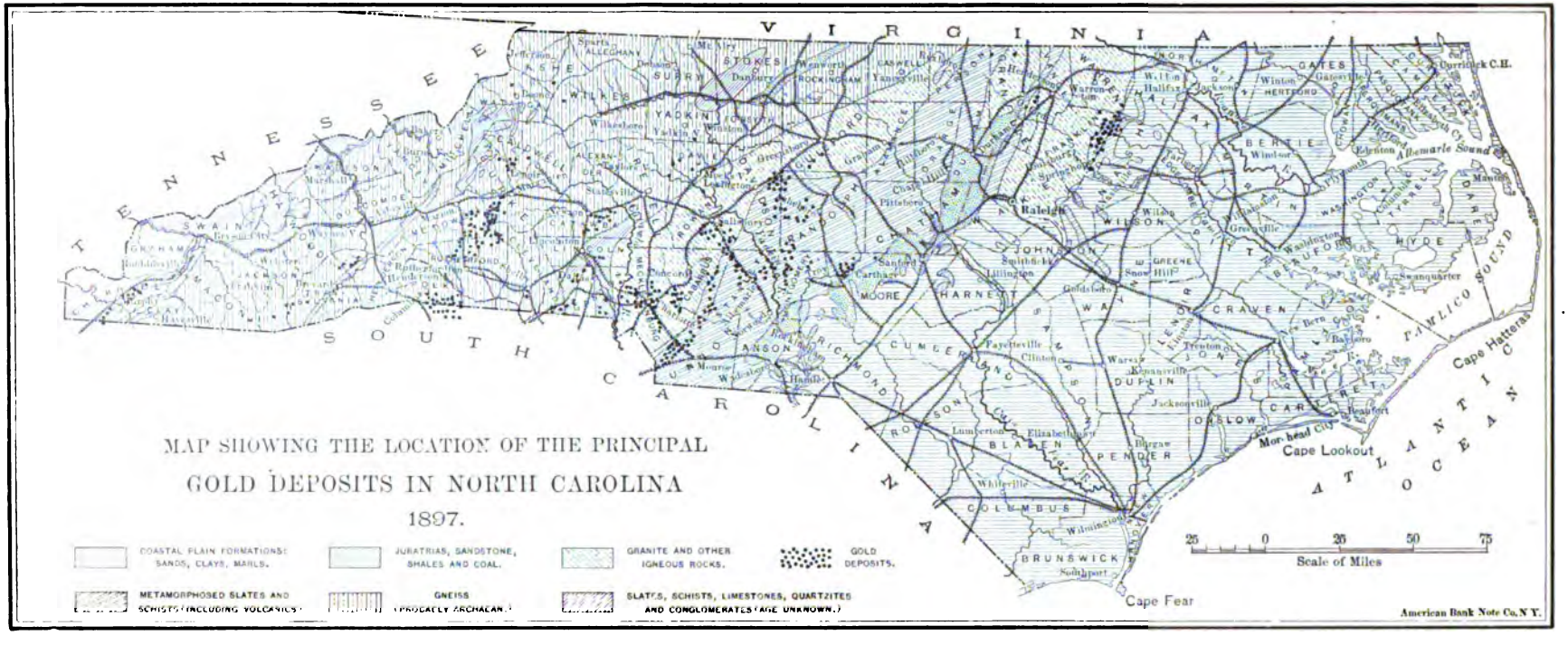

Fig. 3. Outline map of North Carolina. Distribution of gold deposits.

imperfectly interlaminated in the schists and often cutting the same at low angles. The quartz is usually saccharoidal. The mine has been opened to a depth of about 108 feet and, so far as is known, was last worked early in 1894.

The PORTIS mine is situated near Ransoms bridge in the northeastern corner of Franklin county. The country-rock is diorite. The ore-bodies lie in two intersecting belts of reticulated quartz-veins, each about 9 feet in total width. No work further than prospecting has been done on these. Small irregular quartz-stringers occur promiscuously throughout the country-rock, and the saprolites in general are stated to be auriferous. The only work of any consequence done here was surface sluicing and hydraulicking to a depth of 15 to 30 feet. Sufficient water supply and head are difficult to obtain. It is stated that 1000 cubic yards, washed in one of the sluice lines, yielded 1018 pennyweights of gold, the loose vein-rock obtained in this mass assaying about $8 per ton.

THE CAROLINA BELT.

Granville, Person, Alamance, Orange, and Chatham counties are included in this belt, being at its northern extremity; but little work of consequence has been done here. A newly discovered belt of veins has been recently opened three or four miles east of Oxford (Chatham mine); another in the northern part of Granville county, near Adoniram and Venable; and still another near the northwest border of the county, in the copper belt (Holloway mine).

MINES IN GUILFORD COUNTY.

Among the principal mines are the Fisher Hill, Millis Hill, Hodges Hill (Hodgins), Fentress (North Carolina), Twin, Gardner Hill, Jacks Hill, North State (McCullough), Lindsay, Deep River, Beason, Harland and Beard, situated from 3 to 10 miles south and southwest from Greensboro in a general direction towards Jamestown. The country-rock is granitic.

The FISHER HILL and MILLIS HILL mines are five to six miles south of Greensboro. There are two systems of parallel veins, the first running north and south and the second northeast and southwest. The aggregate length of the veins on this property is stated to be 8 or 10 miles. The vein which has been most extensively worked varies from 10 inches to 4 feet in thickness and has been successfully operated at several points. The mill consists of ten stamps and was running in 1886 and 1887.

The HODGES HILL (Hodgins) mine is two miles east of the Fisher Hill. The ore is quartz and chalcopyrite, in a flat vein from 6 inches to 12 feet thick.

The NORTH CAROLINA (Fentress) mine is 9 to 10 miles south of Greensboro. The general strike of the vein is N. 25° E.; its dip ranges from 38° to 60°. The quartz outcrop has been traced for three miles. The ore is chalcopyrite in quartz and siderite, containing gold. It was formerly worked for copper. The mine has been opened to a depth of 310 feet, where the ore-shoot was 80 to 90 feet long and 34 inches wide. The thickness of the vein varies from this to as high as 13 feet. It was last worked in 1856, and the ores which were shipped ranged from 14 to 23 per cent. copper.

The TWIN mine is six miles southwest of Greensboro. There are two parallel veins separated by 4 feet of slate. The strike is N. 40° E. and the dip S.E. The thickness of the vein is about 18 inches, the ore being auriferous quartz, carrying chalcopyrite.

The GARDNER HILL mine is three miles northeast of Jamestown. There are supposed to be three veins on the property. The main vein strikes N. 20° E. and dips westward. Its thickness is from a few inches to 3 feet. The vein-matter is auriferous quartz, carrying chalcopyrite and some pyrite. The wall-rock is granite, with a slaty gouge on each side of the veins. The mine has been opened to a depth of 110 feet. It is stated[1] that the ore ran from $10 to $20 per ton and that the mine yielded $100,000. It is estimated that the present dumps contain 25,000 tons of ore. Tentative assays show $3 to $10 per ton.

The NORTH STATE (McCullough) mine is situated about two miles west of south from Jamestown. The vein strikes northeast and dips 45° to 80° S.E. The mine was opened to a depth of 325 feet, where the vein was 4 to 8 feet thick. At the surface it was 2 feet; at the 60-foot level, 4 feet; at the 90-foot level, 10 feet; and at the 130-foot level, 24 feet in thickness. The ore is quartz carrying gold and sulphurets (pyrite and chalcopyrite). The brown ores extend to a depth of 130 feet and are said to have yielded from $1.50 to $5 per bushel ($15 to $50 per ton).

The last work was done at the depth of 325 feet, where the vein varied from 4 to 8 feet in width. The equipment consisted of 20 stamps and other machinery, which were last operated in 1884.

The JACKS HILL is on the northern, and the LINDSAY on the southern extension of the North State vein.

MINES IN RANDOLPH COUNTY.

The mines are in the central and western part of the county. The country-rock is argillaceous and chloritic schist, probably in large part sheared eruptives. At the Hoover Hill the rock is a massive porphyrite.

[1] Emmons, *Geol. Rept. Midland counties of N. C.*, 1856, pp. 174, etc.

The Sawyer mine is 5 miles northwest and the Winningham, Slack, Winslow and Davis Mountain mines are from 2 to 5 miles southwest of Asheboro.

During 1895 the application of the cyanide process to the ores of the Sawyer was experimented with, but finally abandoned

The HOOVER HILL mine is situated about 10 miles west of Asheboro and 17 miles east of south from High Point. The country-rock is a basic eruptive which is partially brecciated, the included fragments being hornstone. In part the rock is slightly schistose. The ore-bodies consist of belts in this porphyrite, which are pyritic and filled with reticulated quartz-veins from less than 1 inch to 12 inches in thickness. The strike of the belts is N.E. and the dip 30°–60° S.E. The ore-bodies are intersected by pyroxenic dikes. The mine has been opened to a depth exceeding 300 feet. The so-called Briols shoot at this depth furnished ore worth $8 to $10 per ton. The mine was working in June, 1895. It was equipped with a 20-stamp mill in 1882.

The Wilson-Kindley mine is one-half mile southwest from the Hoover Hill, and the formation is similar.

The JONES (Keystone) mine is 18 miles east-southeast from Lexington. The country-rock is a very schistose phase of the brecciated porphyrite described at Hoover Hill. The strike is N. 45° E. and the dip 80° N.W. The ore-bodies consist of separate belts, 12 to 15 feet wide, of the schists, impregnated with auriferous pyrites and quartz-stringers. The entire width of the ore-bearing ground is stated to be 50 to 110 feet. The ore is cheaply mined in open cuts by quarrying. A 40-stamp mill stands on the property. The ore is stated to mill $2. Assay value $2 to $7 per ton. Pan concentrates run $22 per ton. Cyanide experiments have been made in a small temporary plant, and it is stated that several tests of sulphureted ores gave an extraction of 70 to 80 per cent. The mine is at present in operation. The Uharie river, 2 miles distant, is the nearest supply from which water could be furnished by pumping, for hydraulicking and sluicing purposes.

The Herring (or Laughlin), Delft and Parish mines are in the vicinity of the Jones. At the last-mentioned mine free gold is found in association with actinolite.

The UHARIE mine is near the Montgomery county line on the Uharie river. The ore-bodies are similar to those of the Russell, which is a short distance southwest (see p. 52); but unlike that at the Russell, the work here has been underground, the depth of the shaft being 170 feet. A 10-stamp mill was erected in 1887.

MINES IN DAVIDSON COUNTY.

The LALOR (or Allen), LOFTIN, EUREKA and BLACK mines are situated from 2 to 3 miles southeast of Thomasville in the granite. The ores

contain gold, silver and copper. At the Lalor mine the depth of the workings is 140 feet. It was last operated in 1882 by the Campbell Mining and Reduction Company of New York. The mill contains 10 stamps and concentrating machinery. The concentrates contained sufficient copper sulphurets to make a smelting ore.

Two of the more important mines in this county are the Silver Hill and the Silver Valley.

The SILVER HILL (Washington) mine is 10 miles southeast from Lexington. The country is chloritic schist striking N. 35° E. and dipping 57° N.W.; it is accompanied by an eruptive porphyrite similar to that of Hoover Hill. The ore is schist and quartz, carrying a complex mixture of pyrite, galena, zinc-blende and chalcopyrite. The galena is rich in silver. A general average of 200 tests of Silver Hill ore shows:[1]

	Per Cent.
Galena	21.9
Pyrite	17.1
Chalcopyrite	1.8
Zinc-blende	59.2
Silver and gold	0.025
	100.025

The difficulty of successfully treating this complex combination of sulphurets has repeatedly been felt here. A mechanical separation of the galena and blende by buddles and similar machinery was perhaps the most successful of the vast number of concentrating processes tried, but even here the assays of the tailings and slimes showed great loss. The ore was for a time treated with some success, without any separation, for the combined oxides of lead and zinc used in paint manufacture. This class of ore is best adapted to a smelting process in combination with copper ores, such as has been successfully done on the similar ores of the Silver Valley mine. (See p. 49.)

As far as the 200-foot level certain portions of the vein were filled with argentiferous galena, which presented no difficulty in treatment. But below that level the blende gradually increases and finally predominates over the galena.

Various assays of the Silver Hill ores show:

	Carbonate Ores.		Pyritic Ores.	
	(1)	(2)	(3)	(4)
Gold, per ton	$8.27	$2.07	$3.10	$10.34
Silver, "	20.36	4.65	4.01	2.97
	$28.63	$6.72	$7.11	$13.31
Lead, per cent	3.80	31.94	0.67	....
Zinc, "	....	27.28	2.08	....

[1] *Ores of North Carolina*, by W. C. Kerr and G. B. Hanna, 1887, p. 197.

	Galena and Blende Ores.				
	(5)	(6)	(7)	(8)	(9)
Gold, per ton.....	$4.13	$6.20	$4.13	$....	$....
Silver "	3.23	10.73	11.25	25.86	103.44
	$7.36	$16.93	$15.38	$25.86	$103.44
Lead, per cent.....	22.94	56.72	12.57	49.00	52.00
Zinc, "	7.14	....	34.29	....	....

The mine has been worked to a depth of 660 feet by numerous and extensive levels. There are two parallel veins or lodes, known as the East and West, about 28 feet apart. The strike is N.E. and the dip 45° N.W. At the 60-foot level they come together, making 20 feet in width; at the 160-foot level the distance between the veins again widens to 32 feet, and the dip approaches the vertical. At the 200-foot level the width of the west lode is 10 to 15 feet. This mine was discovered in 1838; it was last worked 12 years ago.

The SILVER VALLEY mine is situated 5 miles northeast of the Silver Hill. The character of the country and the ore are similar to those at Silver Hill. The strike of the lode is N.E. with a dip of 45° N.W. The hanging is siliceous argillaceous schist, and the foot-wall, a hard hornstone (devitrified quartz-porphyry). The outcrop is a barren milky quartz, 20 feet wide; the sulphurets appear at a depth of 60 feet. The mine has been opened to a depth of 120 feet. The lode is from 5 to 12 feet in width and consists of alternate bands of slate, quartz and sulphurets, the latter seams being from 3 to 18 inches thick. A 20-stamp mill stands on the property.

Some assays of the Silver Valley ores show:

	Galena and Blende Ores.		
	(1)	(2)	(3)
Gold, per ton.....	$....	$4.13	$....
Silver, "	17.19	176.49	38.14
	$17.19	$180.62	$38.14
Lead, per cent.....	15.54	55.25	38.80
Zinc, "	31.43	11.24	32.00

	Concentrates.			
	(4)	(5)	(6)	(7)
Gold, per ton.....	$4.13	$4.13	$1.03	$1.65
Silver, "	23.01	44.74	13.08	14.34
	$27.14	$48.87	$14.11	$15.99
Lead, per cent.....	11.18	47.62	9.63	8.13
Zinc, "	27.70	12.68	27.84	33.54

The mine was last operated in the latter part of 1893, and the ores were smelted in a furnace at Thomasville (North Carolina Smelting Co.). Many attempts have been made at various times to treat these

complex ores, but unsuccessfully until this last time. A description of this smelting process, by Dr. G. W. Lehmann, of Baltimore, Md., is therefore deemed of interest and is given here in his words:

"The smelting plant situated at Thomasville, N. C., on the line of the Southern Railroad and within 13 miles of the mines of the Silver Valley Mining Company, was erected especially for the treatment of the refractory ores from this mine.

"The composition of the ore is zinc-blende, galena, iron sulphides, together with some little copper, silver and gold. An average analysis representing a large lot delivered at the smelter gave: Zn., 28 per cent.; Pb., 12 per cent.; Cu., 0.5 per cent.; Ag., 21 ounces per ton; Au., 0.06 ounces per ton. Quite a number of patent processes have been in operation since the last 10 years at the works in order to profitably reduce the several metals, but none of these processes have gone beyond the experimental stage, since none of them proved a commercial success, until about two years ago. At that time Mr. Robert Nininger, of Newark, N. J., erected a plant which deals with the subject of treating refractory ores successfully. The plant consists essentially of:

"1. Down-draft jacket furnace connected with two horizontal jackets, one on each side of the furnace;

"2. Two condensers connecting with the horizontal jackets;

"3. Vat house with a series of large vats to receive the flow of liquor from the condensers and to collect the lead and zinc residues;

"4. A separate plant for the treatment of the lead residues;

"5. A separate plant for the treatment of the zinc residues.

"The down-draft furnace, as far as charging and general construction is concerned, is operated in a similar manner as any ordinary jacket-furnace, but the arrangement of the tuyeres is different and the current of air from the blowers necessary for the complete combustion of the refractory ore is carried down through the charge; thence through the horizontal jackets, the condensers, through two powerful suction blowers along a series of dust chambers, and out through the stack. A constant spray of water meeting the volatile metallic fumes of lead and zinc (together with what silver the zinc fumes carry along) in the two condensers, deposits all the metallic products and carries them with the liquor into a series of vats where the lead sulphite or sulphate is deposited on the bottom of the vats, carrying the silver with it, whilst the zinc remains in solution and is precipitated out of this solution as zinc oxide.

"During the operation the slag is drawn off from openings near the bottom of the horizontal jackets near the furnace proper, whilst the matte is collected in the well of the furnace and tapped. This matte carries the copper, gold, and most of the silver. It is necessary to prepare the charges to the furnace so as to have not less than 5 per cent. of copper in your charge; otherwise the resulting matte would be too low in copper and would have to be treated over and over again. Gold concentrates and even dry ores can be used with advantage as fluxes and will help to make the process more profitable."

The cause of closing down the furnace was the difficulty of obtaining sufficient copper ores for fluxing.

During the summer of 1896 some testing work was done on the placer deposits forming the bottom land along a small creek that traverses the property. The plant consisted of an iron washer operated by a hydraulic stream, riffled sluices, amalgamating tables and rockers.

Its capacity is from 40 to 50 tons per day. It was estimated that the minimum yield of the ground was $2 per ton, and from that up to $4.

Some prospecting was also done on a gold-bearing quartz-vein situated on the west side of the creek. A 40-foot shaft exposed 7 feet of vein matter, consisting of quartz and schists carrying pyritic sulphurets. An assay of an average sample is stated to have given a value of $9.55 per ton. Assays of the more highly pyritic portion (about 4 feet in width) showed $19.06 per ton, and it is supposed that this material can be concentrated to $60.

The WELBORN (or Smith) mine, which is 2 miles west of the Silver Hill, carries similar ores.

The CONRAD HILL mine is situated 6 miles east of Lexington. The country-rocks are silicified chloritic and argillaceous schists, striking N. 10°–20° E., and dipping 80° N.W. There are two systems of veins, one parallel to the strike of the schists, and the other cutting the same at various angles. The vein-matter is quartz and siderite, carrying chalcopyrite and gold.

A number of these veins have been opened and worked by three different shafts, the deepest of which, the main or engine shaft, is 400 feet deep.

The thickness of the ore-bodies varies in different portions of the mines from less than 1 to as much as 20 feet.

The method of preparing and treating the ores at the time the mine was in operation, was to partially sort underground, and then still further hand-cobb and pick on the surface, which product went to the copper works; the remainder was crushed and jigged and the heads added to the hand-picked ore above; the tails were counted as waste, and the middlings were sent to the stamp-mill and amalgamated, where the tailings from the battery were again partly concentrated by buddles and blankets, and the concentrates sent to the copper works.

The treatment for the extraction of copper at first was to smelt the roasted ore in a shaft furnace for matte, from which, after re-smelting, black copper was obtained and refined. Smelting was superseded by the Hunt and Douglas wet process. The crushed roasted ore was subjected to a bath of protochloride of iron, for the conversion of the insoluble copper minerals to the soluble chloride; after leaching, the copper was precipitated by metallic iron and then refined. The residues were milled and amalgamated in order to obtain the gold.

MINES IN MONTGOMERY COUNTY.

The mines of this county are situated in the northern-central and northwestern parts, along the range of the Uharie mountains.

The CARTER and REYNOLDS mines are some 6 miles northeast of Troy. They have been worked to a depth of 100 and 80 feet, respectively. Telluride of gold is stated to occur here.

On the nortwest side of the Uharie mountains is a series of gravel mines situated in a line between the mountains and the Uharie river. Among others may be mentioned the Bright, Ophir[1] (Davis), Spanish Oak Gap, Dry Hollow, Island Creek, Deep Flat, Pear Tree Hill, Toms Creek, Bunnell Mountain, Dutchmans Creek, and the Worth. The available portions of these placers have been exhausted so far as the present supply of water will answer. The Beaver Dam placer is located about 5 miles west of Eldorado.

The SAM CHRISTIAN mine is situated on the west side of the Uharie mountains about 9 miles southwest of Troy.

The property contains 1350 acres. It was at one time extensively worked as a gravel mine by the Sam Christian Company, of London, England (the last operations were in 1893), the water being obtained by pumping from the Yadkin river, about 2½ miles distant. The plant consisted of two Worthington pumps and five 100 horse-power boilers, with a capacity of delivering to the mine 5,500,000 gallons in 24 hours, through a 20-inch steel flanged pipe. The elevation of the point of discharge above the point of supply was 416 feet.

The two principal channels were the Dry Hollow and the Sam Christian cut. The thickness of the gravel varied between 1 and 3 feet. The gold was coarse, mostly in nuggets from 5 to 1000 dwts. The country-rock is the Monroe slate, accompanied by large masses of volcanic breccias and cherty felsites (devitrified quartz-porphyry) which contain many small quartz-veins from ½ to 3 inches in thickness, striking N. 70° W. and dipping 60° N.E. Several shafts have been sunk on some of these narrow veins; but the attempts at deep mining were failures.

Most of the deep mines are situated in the extreme northwestern corner of the county, with Eldorado in their center.

The RUSSELL mine (Glenbrook Mining Company), is about 3 miles northeast from Eldorado and but a short distance from the Randolph county line. The country-rocks are argillaceous slates, both of soft and silicified types. Calcite occurs as a coating and in veinlets. In part at least, if not altogether, these slates are sedimentary; the bedding and cleavage planes usually coincide, though not always. The strike and dip is very variable. Diabase dikes occur in the country, but not in close proximity to the mine. The ore-bodies consist of parallel belts in the slates, impregnated with iron sulphurets (2 to 4 per cent.) and free gold, together with quartz-stringers. There are at least six of

[1] The saprolites have been explored here, and a belt 30 feet wide was found to mill $3 per ton.

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FORTY-STAMP MILL AND CYANIDE PLANT, RUSSELL MINE, GLEN BROOK, N. C.

these belts within a distance of 2000 feet across the strike. One of the largest is opened by the Big Cut, an open pit about 300 feet long by 150 feet wide by 60 feet deep (Plate II). On the eastern edge of this cut is a shaft 150 feet deep, from the bottom of which the ore has been stoped upward. It is stated that the entire material from the cut averaged about $2 per ton, mill-yield. There were some rich streaks from 4 to 5 feet wide which went much higher. Two stamp-mills are situated on the property; the new mill contains 40 stamps (Plate III) and the old one (now in ruins) 30 stamps. It was proposed in 1895 to treat the Russell ores by the cyanide process; and the American Cyanide Gold and Silver Recovery Company, of Denver, Col., erected a 30-ton plant in the following year, and it is stated that experimental tests and calculations demonstrated the ability to treat the ore for $1 per ton, on a 100 ton scale, with an extraction of 85 to 90 per cent.

The APPALACHIAN (or Coggins) mine is located near Eldorado. It is quite similar in character to the Russell, showing large bodies of low-grade ore. The depth of the last workings was 160 feet. A 40-stamp mill was erected in 1887, and was moved to the Jones mine, Randolph county, in 1896.

The MORRIS MOUNTAIN (Davis or Dutton) mine is one mile west of the Appalachian, and the ore-bodies are similar to those of the Russell and the Appalachian.

The RIGGON HILL mine is located 3 miles east of Eldorado. The ore-body consists of a quartz-vein, 2½ feet in thickness, lying in and with the slate country. It has been opened by a shaft 100 feet in depth. Some very high-grade ores (both in gold and silver) are reported from here. Prospecting work was being done during the past summer.

The STEEL mine is situated about 2 miles southeast of Eldorado. The country is silicified schist, striking N. 25° E. and dipping 70° N.W. The ore-bodies (9 to 12 feet in thickness) consist of the schists impregnated with sulphurets (galena, blende, chalcopyrite and pyrite) and intercalated with quartz-stringers or seams from less than one up to twelve inches in thickness. The combined thickness of these ore-seams is rarely less than 15 inches, and is sometimes more than 3 feet. The ore contains gold and silver in galena, blende, chalcopyrite and pyrite. Occasional bunches of the ore have been extremely rich, and assays of the entire mass of the vein-matter have shown values from $20 to $160 per ton. The depth of the mine is 220 feet. It was last operated by the Genesee Gold Mining Company, the ores being treated in a 40-stamp mill.

The Saunders mine is an extension of the Steel.

The MORATOCK mine is situated 8 miles south of Eldorado. The country-rock is a massive, devitrified quartz-porphyry and volcanic

breccia. It is very sparingly impregnated with sulphurets (pyrite and some chalcopyrite). Several small quartz-veins (less than 1 inch in thickness) intersect the mass. The mine consists of a small quarry opening in the quartz-porphyry. A 10-stamp mill, equipped with a cyanide plant, stands on the property and was last in operation in July, 1893. The ore was reported to be of too low grade to be profitably treated.

MINES IN STANLY COUNTY.

The mines are located in the northeastern portion of the county, more or less on the line of the Southern Railroad branch running from Salisbury to Norwood. Among the more important properties are the Haithcock, Hearne, Crawford, Lowder, Parker, Crowell and Barringer.

The HAITHCOCK and HEARNE mines are about two miles northwest of Albemarle. The country-rock is clay-slate, striking N.E., and associated with eruptives. The quartz-veins are stated to be from 2 to 6 feet in thickness.

The CRAWFORD mine, situated 4 miles northeast from Albemarle, is a newly discovered placer, and is described in detail on p. 91.

The LOWDER mine is situated 4 miles west of Albemarle. It was opened in 1835, but has not been operated since the war. Previous to that time it was worked along the outcrop and to a depth of 65 feet. The quartz-vein is stated to be 3½ feet in thickness, lying approximately with the slates in strike and dip. During the summer of 1895 the mine was unwatered, and some prospecting work was carried on.

The PARKER mine (the New London Estates Company, L'td.) is situated at New London, 9 miles northwest of Albemarle. The property comprises about 1200 acres. It is now in litigation. The country slates resemble those of the Monroe type (see p. 16); they are intruded by successive flows of greenstone porphyry and more basic eruptives, in part brecciated. The mine shafts have disclosed at least two volcanic sheets, from 2 to 3 feet thick each, lying horizontally and separated by sedimentary slates. In places the greenstone is squeezed into nearly vertical schistose masses. The country is intersected by numberless quartz-stringers and several larger quartz-veins, which are auriferous. The principal work at the Parker consisted of hydraulicking (see Plate IV) in several old gravel channels, which are stated to have yielded over $200,000. The gold was coarse, usually in nuggets from a few pennyweights up to 3 pounds. The fineness of the gold is 950 to 970.

The value of the gravel is stated to vary from 44 cents to $2.40 per cubic yard.

In one of the hydraulic cuts the bed-rock underlying the grit was decomposed greenstone. Test-pits have shown that this bed-rock is but

HYDRAULIC MINING, PARKER MINE, STANLY COUNTY, N. C.

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SLUICES, PARKER MINE, STANLY COUNTY, N. C.

a sheet of greenstone about 3 feet thick, and that it is underlain by another auriferous gravel deposit, which may be considered virgin ground, as no attempt has yet been made to work it. There would be no great difficulty in getting a sluice on the bed-rock beneath this lower grit, with sufficient fall to carry off the tailings.

The hydraulicking plant is very extensive. It consists of a Worthington compound duplex condensing pump, with two 100 H. P. boilers (using 7 cords of wood per day, at $1 per cord), situated on the Yadkin river, 4¼ miles from the stand-pipe at the mine, and 340 feet below the same. The pipe-line on the lower lift is 20 inches in diameter, flange-riveted, made of $\frac{3}{16}$-inch steel; on the upper lift is a similar steel pipe 12 inches in diameter. Expansion-joints are placed every quarter of a mile, and the full length of sleeve (8 inches) is necessary to take up the maximum expansion and contraction of the pipe caused by changes of temperature. The capacity of the pump is 1,500,000 gallons in 12 hours; the head furnished from the top of the stand-pipe to the mine-workings is about 90 feet. (Plate V.)

Besides the gravel channels at the Parker, the saprolites are, in general, auriferous; and a combination sluicing and milling process (Dahlonega method, see p. 107) was at one time attempted here. The bank was undercut with powder and the shattered mass moved with the giants. The material ran about 50 cents a ton in the mill; but only a small percentage of it was quartz, and an attempt to select the latter proved unsuccessful. The tailings in the mill were reasonably low; but the loss of fine gold in the overflow from the mill-tank, in connection with the exhaustion of the richer available saprolites, led to the abandonment of the process.

The mill is a 10-stamp one, built by the Mecklenburg Iron Works of Charlotte, N. C. The weight of the stamps is 650 pounds. In the Dahlonega practice 4 drops were given 80 times per minute, and round punched screens were used; there were no inside plates. About 50 per cent. of the gold was saved in the mortars between the dies. The total cost of milling (including 1 cord of wood at $1), with 1 hand on each shift at $1, was $4 per 24 hours.

The last work done at the Parker (fall and winter of 1895) was that of prospecting some of the larger quartz-veins on the property. The Ross shaft was sunk to a depth of 130 feet and a vein was opened by a crosscut, showing sulphurets of iron and copper in white quartz, which gave assay values ranging from $3 to $12 per ton. The same vein had been exposed in a 130-foot shaft to the west of the Ross, where assays of the quartz showed values of $3 at the 85-foot and $7 at the 130-foot level.

The dimensions of the Ross shaft are 5 feet 6 inches by 11 feet inside

measurements, with three compartments, the ladder-way being in the center. The timbers (10 by 12 inches, white oak) are placed in square sets, with 5 feet centers. The cost of timber is $7 per thousand. The cost of the shaft (including timbering) was estimated at $10 per foot for the first hundred feet, $12 for the next hundred, and $15 for the last fifty feet.

Cost of labor:

Mine foreman (who also does the framing)	12-hr. shift,	$1.50
Helper to same	" "	1.00
Blacksmith	10-hr. "	1.00
Underground men	12-hr. shift, 75 to 85 cents.	

The CROWELL mine is situated near the Parker. The ore-body is a pyritic belt in the country slate, from 4 to 7 feet in thickness, with a narrow pay-streak. The strike is N. 10° W., and the dip 45° N.W. The mine has been worked to a depth of 125 feet.

The LITTLE FRITZ (formerly the Culp) mine is situated near Gladstone. Some prospecting work has lately been in progress here, and an Elspass frictional roller quartz-mill was erected.

The BARRINGER mine is situated 4 miles southeast of Gold Hill. The gold is associated with limestone, and very rich ores are stated to have been mined here.

MINES IN MOORE COUNTY.

The mines are situated in the northern and northwestern parts of the county. The Jura-trias sandstone, the eastern limit of the Carolina belt, passes in a southwesterly direction through the central part of the county, near Carthage.

The BELL mine is situated 8 miles north-northwest from Carthage. The country-rock is a garnetiferous chlorite-schist, striking N. 55° E., and dipping 75° N.W. The ore-body consists of a 4-foot belt in the schists, containing a small percentage of finely disseminated pyrite and intercalations of siliceous seams from ⅛ to 4 inches in thickness. The entire vein-matter is said to run $12 a ton. It is stated that the pay-streak, 4 to 8 inches thick, lay against the foot-wall, and that about 2 feet of the material on the foot-wall side was mined and milled, yielding as much as $30 a ton. The mine has been worked to a depth of 110 feet and for a length of 800 feet.

The Grampusville mine is 3 miles southwest of the Bell.

The BURNS mine[1] is situated 11 miles west-northwest from Carthage, on Cabin creek. The country is sericitic and chloritic schist, in part silicified. The strike is N. 20° E., and the dip 55° N.W. The ore-

[1] See article by H. M. Chance, *Eng. and Min. Jour.* vol. lxi, p. 132, 1896.

bodies consist of certain belts of the country, impregnated with pyrite and quartz in lenticular stringers. The ore is mined in large open cuts, 20 to 100 feet wide and 50 feet deep. The average ore is stated to run from $2.50 to $3 per ton in free gold. In 1894 the ores were being treated in five Crawford mills by the Columbia Mining Company, but the operations did not apparently prove successful. In 1895 the Cabin Creek Mining Company built a 10-stamp mill, with bumping-tables for the concentration of the sulphurets, for the treatment of which it has been proposed to introduce the cyanide process.

The Clegg, Cagle, Bat Roost, Shields, and Brown mines are situated from ½ to 3 miles west and north of the Burns. The character of the country-rock and of the ore-bodies at these is similar to that of the Burns.

MINES IN ANSON COUNTY.

A small patch of crystalline rocks, lying on the south side of the Jura-trias sandstone, is gold-bearing. Two mines, the Hamilton (Bailey) and the Jesse Cox, are situated about 2 miles southwest of Wadesboro. They are not working at present.

MINES IN ROWAN COUNTY.

The mines are located in the southeastern portion of the county in three general groups:

1. In a line extending from 2 to 9 miles southwest of Salisbury, and 1 to 3 miles east of the Southern Railroad, including the Hartman, Yadkin, Negus, Harrison, Hill, Southern Belle, Goodman, Randleman, and Roseman mines. Not enough is known of these to admit of an intelligent description.

2. Two to seven miles east and southeast of Salisbury, in the Dunns Mt. granite area, including the Dunns Mt., New Discovery, Bullion, and Reimer mines. Of these, the Reimer is fully described on page 117, and will serve as a type for the others.

3. Nine to ten miles southeast of Salisbury in the metamorphic schists, including the Gold Hill, Dutch Creek, Gold Knob, Holtshauser, Atlas, and Bame mines.

The GOLD HILL district was at one time one of the most important mining centers in North Carolina, if not in the whole South; although at present no work of consequence is being carried on there. It is situated about 14 miles southeast of Salisbury, in the southeast corner of Rowan county, extending into Cabarrus county on the south and Stanly county on the east. The country-rocks are chloritic and argillaceous schists, striking N. 25° to 30° E. and dipping 75° to 85° N.W. A diabase dike cuts the schists near the village of Gold Hill. The char-

acter of the ore-bodies is that common to these schists elsewhere, consisting of certain belts in the schists filled with pyritic impregnations and imperfectly conformable lenticular veins and stringers of quartz. The principal part of the gold-bearing zone is 1½ miles long from northeast to southwest and ⅔ of a mile wide. There are well-defined veins in the district, among which the more prominent ones are the Randolph, Barnhardt, Honeycut, Standard, Trautman and the McMackin. Some of these, such as the Trautman and McMackin, are heavy in argentiferous galena.[1] (See fig. 4, p. 59.)

The first gold was discovered here in 1842, and it is stated that in the next 14 years the total production of the various mines was $2,000,000. In 1853 there was a population of about 2000 in the Gold Hill camp, at which time the Gold Hill Mining Company operated 5 Chilean mills and 40 to 50 rockers, working 300 hands. Between 1845 and 1850 the Randolph shaft was put down to a depth of 750 feet. This is the deepest gold-mine shaft in the South. The Randolph vein was worked in three principal lenticular ore-shoots, pitching to the northeast, and varying from 50 to 200 feet in length and from a few inches to 6 feet in width. It is stated that remarkably rich ores were obtained in those days, large quantities yielding from $100 to $500 per ton in the mill. In 1881 the Randolph shaft was unwatered to the depth of 400 feet.

The method of working the Gold Hill ores in the earlier days is described on p. 34.

According to Emmons,[2] the amount of gold produced from December, 1853, to June, 1855 (inclusive), as derived from the company's books, was $136,636.76, and the expenses were $76,429, leaving a net profit of $60,207.76 for 19 months. During the time which includes the foregoing record, however, only the ore taken from the poor pockets was worked.

It is estimated by some that up to 1874 $3,000,000 worth of free gold in the ore was produced. In 1871, Mr. Amos Howes, the owner at that time, worked 3 Chilean mills, treating 7 tons of ore per day. The total daily expenses were $95.51, or $13.64 per ton. Of 8400 tons treated by Mr. Howes he produced $200,000, or an average yield of $23.81 per ton. It is estimated that only 33 per cent. of the gold was saved by this method of amalgamation, 67 per cent. going off in the tailings.

The first stamp-mill (20 stamps) was erected in 1881. The last regular work was done in 1893 by the New Gold Hill Company, Mr. Richard Eames, manager, when the ores from the Barnhardt vein, which are high in copper, were milled in a 10-stamp mill. (See p. 60.)

[1] For more detailed description of the structure of the region see Bull. 3; *Gold Deposits of N. C.*, 1896, pp. 83–91.

[2] *Geological Report of the Midland Counties of North Carolina*, 1856. E. Emmons, pp. 160 *et seq.*

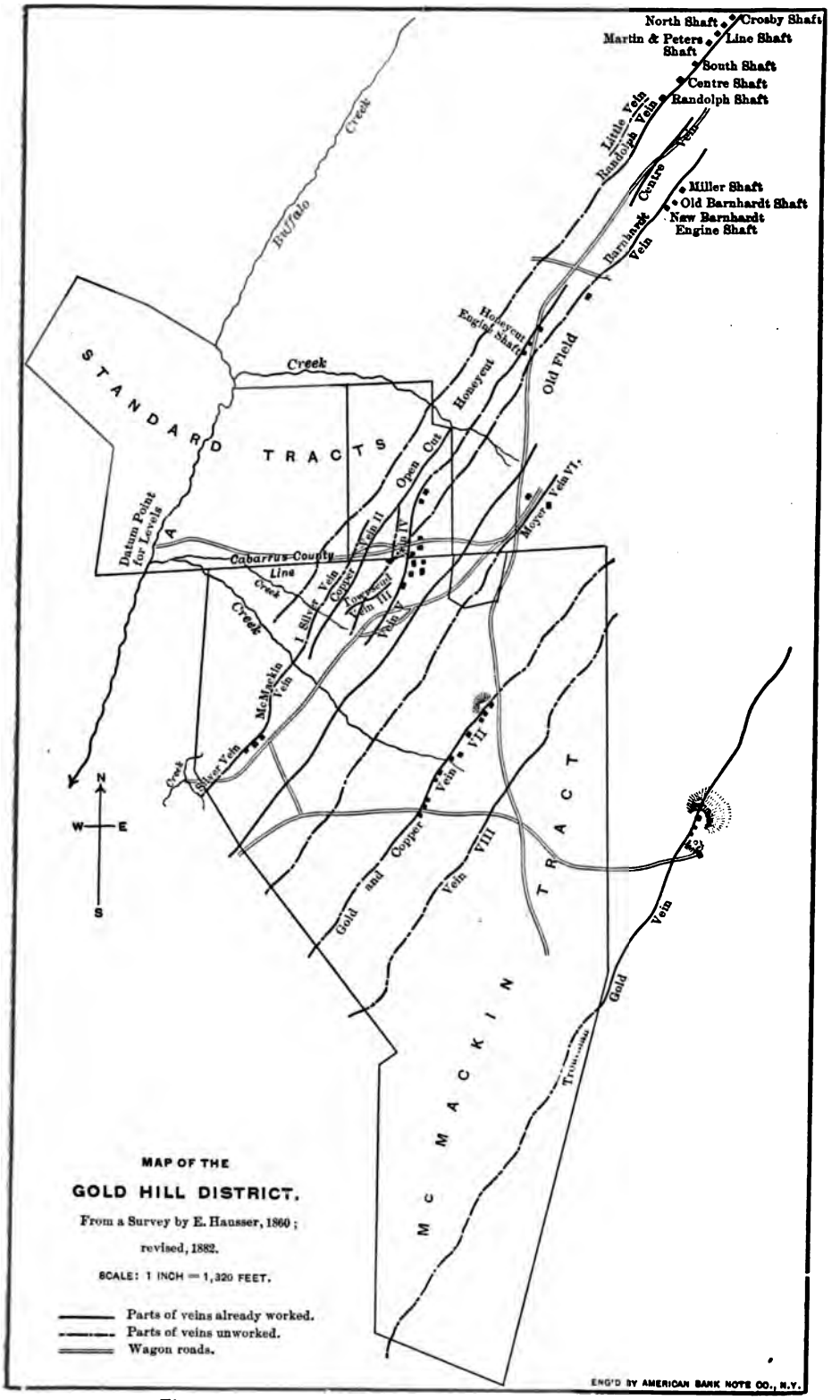

Fig. 4. Map showing distribution of the Gold Hill veins.

Mr. Eames carried on some laboratory experiments in 1892 for a cyanide treatment of the Gold Hill ores, and obtained an extraction of 60 per cent. on 100 pounds treated. During the summer of 1895 Mr. Bloomer, of London, experimented with cyanide, but with what result is not known. Chlorination of the Gold Hill ores has been advised but never carried out. No earnest attempts have been made to treat the sulphurets on a working scale. Plate VI shows the Eames stamp-mill.

For the past number of years the only work at Gold Hill has been done by tributors, who cart the decomposed material from the old mine dumps to the Barnhardt mill, receiving 50 per cent. of the yield. This material mills about $1.50 per ton. The pulp from the stamps flows directly over a line of blankets 24 inches wide, which are washed every 20 minutes in a tank; and the concentrates are treated in a series of hollowed log-rockers, 12 to 14 feet long, provided with quicksilver riffles (see Plate I, p. 30), the tailings flowing off into the creek.

At the ISENHOUR mine (Cabarrus county), 1½ miles southwest from Gold Hill, the ores from a 3-foot vein were ground (during the summer of 1895) in a Howland pulverizer of 6 tons capacity per 24 hours. The pulp was run over blankets, the washings from which were treated in rockers, as at the Barnhardt mill, with a yield of about $2 from ores that assayed from $5 to $7 per ton.

The GOLD KNOB mine is some 5 miles northwest of Gold Hill in the same general zone of schists. As many as 11 separate parallel ore-leads have been explored. Of these, the Holtshauser vein was again opened during the summer of 1895.

The DUTCH CREEK mines are in the vicinity of Gold Knob. It is stated that there are 20 veins on the property, some of which are copper-bearing. The strike of the veins is generally northeast; but there is a second system striking more northerly and intersecting the first. The more or less oxidized surface ores have been largely worked out down to the water-level, below which point the sulphurets remain practically unchanged.

The Atlas and Bame mines are on the southwest extension of the Dutch Creek veins.

MINES IN CABARRUS COUNTY.

The metamorphic schists occupy a narrow strip along the eastern edge of the county, in which are located a series of mines which might be considered an extension of the Gold Hill zone. Such are the Widenhouse, Nugget (Biggers), Eva Furr, Allen Furr, Rocky River, Buffalo, Reed and Phœnix.

The other mines of the county are situated in the granitic rocks near Concord and to the southeast and south of Concord. Such are the Joel Reed, Montgomery, Quaker City, Tucker and Pioneer Mills mines.

GOLD HILL MINE: BARNHARDT SHAFT AND EAMES STAMP-MILL.

The NUGGET (Biggers) mine is situated 12 miles southeast of Concord, near Georgeville. The principal operations during the past three years have been hydraulicking on a gravel channel, similar to that at the Crawford mine in Stanly county. The gold is coarse, usually in nuggets. Quartz-veins carrying argentiferous galena have also been superficially explored.

The ROCKY RIVER mine is 10 miles southeast of Concord. The country is chloritic schist striking N. 20° E. and dipping 70° N. W. Several lenticular quartz-veins, lying more or less with the schists, have been explored. The quartz contains pyrite, galena, blende and chalcopyrite. During 1895 Mr. Wayne Darlington, M. E., carried on some prospecting work on one of these in a shaft 130 feet deep, the total length of the drifts being about 200 feet. In the 80-foot level the quartz was 2½ to 3 feet thick; but it pinched out at 130 feet. Some of the ore was heavy in sulphurets and rich in gold. Crosscuts have exposed parallel quartz-bodies. However, it appears that no regular quartz-vein can be depended on. The more or less silicified schists enclosing the quartz are impregnated with sulphurets and intercalated with small quartz-stringers, which, taken together, will make large bodies of low-grade ores. It is in such that the possible value of the mine must be looked for.

The Buffalo mine, 1 mile northeast of the Rocky river, presents similar conditions.

The REED mine is 1½ miles southeast of the Rocky river. It is the site of the first discovery of gold in North Carolina. In 1799, a 17-pound nugget was found, and in 1803 one weighing 28 pounds. The placer ground was worked vigorously in former years and much nugget-gold taken out. The estimated yield from 1804 to 1846 is $1,000,000. During the year 1895 work at this mine was revived, but it appears to have been simply of a prospecting character and short-lived. On April 11, 1896, a nugget weighing 246.83 ounces Troy was found. It contained 120.87 ounces (10.072 pounds) fine gold, and 5.99 ounces fine silver. During the latter part of 1896 placer work was being carried on in a small way. The chloritic schists are accompanied by a large body of greenstone, intersected by numerous quartz-veins varying in thickness from 4 inches to 3 feet. Some of these are gold-bearing, and were formerly worked by a shaft 120 feet in depth.

The PHŒNIX mine is situated 7 miles southeast of Concord. The country schists are accompanied by a large mass of diabase, in which the auriferous quartz-veins are confined. The main vein is the Phœnix, which was extensively and successfully worked under the management of Captain A. Thies, now of the Haile mine, S. C. Operations ceased here about 1889. The Phœnix vein strikes N. 70° E. and dips 80°

N.W. It varies from 12 inches to 3 feet in thickness. The ore-shoot, which is 300 feet long and pitches to the northeast, has been worked out from the 100 to the 425-foot level. The shaft was sunk to 485 feet on the dip of the vein, but not drifted from. The vein in the shaft averages 30 inches; but the rich pay-streak, lying on the hanging wall, is only from 2 to 3 inches thick. It is believed, however, that if the vein were drifted on at the 425-foot level the 300-foot ore-shoot just referred to would be reached again. Another ore-shoot, the Big Sulphur, is situated 300 feet southwest of the above, and has been worked to the 180-foot level. The ore in the bottom of this shaft (the pump shaft, 213 feet deep) is stated to be 14 inches thick.

Captain Thies's work was confined to the 300-foot shoot. The ore was quartz, carrying 3 to 60 per cent. of sulphurets (pyrite, chalcopyrite and traces of galena). Barite and calcite occur in the gangue. The cost of mining was $4 per ton. Assays show from 1½ per cent. to 3 per cent. of copper. The mill yield was $10 per ton, besides which the sulphurets contained $7.50. The concentrates ran $30. Chlorination was first introduced here in 1880. This was the Mears process, later developed into the Thies process. A full description of this, with costs of working at the Phœnix mine, has been given in a paper by Dr. William B. Phillips.[1]

The mill and chlorination plants are now dismantled.

The Barrier, Furness, and Gibb mines adjoin the Phœnix. The Faggart is 3 miles to the northeast, and the Barnhardt is 1½ miles east of the Faggart.

The TUCKER (or California) mine is 1 mile south of the Phœnix. It was last worked in 1884, by a shaft 175 feet deep, and levels 117 feet in total length. The quartz-vein was 15 inches wide, and showed values of $15 per ton. In 1882 the Plattner chlorination process was introduced here; but this was later superseded by the Mears process.

The QUAKER CITY mine, which is 3 miles north of the Tucker, has not been worked for the past ten years. There are three shafts on the property, the deepest one being 80 feet. The vein is stated to be from 2 to 5 feet wide.

The Pioneer Mills group of mines is situated 13 miles south of Concord. No work has been done here since the war. The granite is accompanied by large masses of basic eruptive rocks.

MINES IN UNION COUNTY.

The mines are situated in the metamorphic slates in the western part of the county. Among the more important may be mentioned the

[1] "The Chlorination of Low-grade Auriferous Sulphides," *Trans. Am. Inst. Min. Engs.*, xvii, pp. 313-322.

Crowell, Long, Moore, Stewart, Smart, Hemby, Lewis, Phifer, Davis, Bonnie Belle, and Howie mines.

The Long, Moore, Stewart and Smart are characterized by the presence of complex sulphurets (pyrite, galena, blende and sometimes chalcopyrite). At the Moore mine the gold is associated with calcite, which exists in a pay-streak 4 inches thick on the hanging wall of a 5-foot quartz-vein.

The Bonnie Belle (Washington) mine is situated 8 miles west of Monroe. The country is argillaceous schist silicified in varying degrees, striking N. 55° E. and dipping steeply N.W. The ore-deposit consists of pyrite and quartz impregnations in the schists. The width of the ore-bearing belt is stated to be 14 feet. It is intersected by a diabase dike. The mine was in operation during the fall of 1894. Ores assaying from $4 to $5 per ton were treated in a Chilean mill and four drag-mills, of 10 tons capacity per 24 hours; the pulp was discharged on amalgamated copper plates and thence to a Gilpin county bumping-table. The concentrates assayed $22, and the tailings 50 cents per ton.

The Howie mine is 1 mile southwest of the Bonnie Belle. The ore-bearing slates are said to have a total width of 400 feet, within which there are as many as 8 so-called parallel veins, varying from 18 inches to 16 feet in thickness. Sulphurets are rare, the gold occurring mainly as fine films on the cleavage planes of the more or less silicified slates. It is stated that the ore, when last mined, yielded $13 to $14 in the mill. The mine has been opened to a depth of 350 feet. Numerous diabase dikes intersect the ore-bodies, which are said to be richer in the vicinity of the dikes.

The Monroe slates in the vicinity of Monroe contain some narrow auriferous quartz-veins, but they are scarcely of economical importance, at least so far as present explorations have gone.

MINES IN MECKLENBURG COUNTY.

This has been one of the most important and active gold-mining counties of the State.

The mines are distributed over the entire county, around Charlotte as a center. Among the more important are the Davidson Hill (1 mile west of Charlotte), St. Catherine, Rudisil, Clark (2½ miles west of Charlotte), Stephen Wilson (9 miles west of Charlotte), Smith and Palmer, Howell, Parks (1 mile northeast of Charlotte), Taylor and Trotter (3 miles southwest of Charlotte), Brawley (4 miles west of Charlotte), Arlington (6 miles west of Charlotte), Capps, McGinn, Alexander (8 miles northwest of Charlotte), Dunn (7 miles northwest of Charlotte),

Henderson (7 miles northeast of Charlotte), Ferris, Tredinick (7 miles southeast of Charlotte), Ray (9 miles southeast of Charlotte), Simpson (10 miles southeast of Charlotte), and Surface Hill (10 miles east of Charlotte).

The RUDISIL mine is 1 mile south of Charlotte. In the upper part of the mine the country is a silicified, chloritic and argillaceous slate. At a depth of 200 feet this gives place to a crystalline eruptive rock. The ore-body consists of two parallel veins close together and separated by slate; they are said to vary in thickness from 2 to 6 feet. The strike is N. 30° E. and the dip 45° N.W. The mine has been worked to a maximum depth of 300 feet in three principal shoots, some of which furnished very rich though highly sulphuretted ores. The largest of these shoots had a maximum length of 100 feet and a maximum thickness of 15 feet; it pitched towards the south, and was followed down to below the 300-foot, but never found in the 350-foot level. No attempt at concentration and treatment of sulphurets was made.

The Smith and Palmer and the Howell mines are supposed to be on the southwestern extension of the Rudisil.

The ST. CATHERINE mine is on the northeastern extension of the Rudisil, and the general features are the same. The deepest workings are at the 370-foot level. It is reported that no large chimneys of solid high-grade ore were found below the 250-foot level; but between the 200 and 370 a large shoot, 4 to 60 feet wide, of low-grade ore has been worked. The ores were treated by battery amalgamation, and the sulphurets were concentrated; these were probably shipped north or elsewhere for smelting.

The CAPPS mine is 5½ miles northwest of Charlotte. There are two convergent veins, the Capps striking N. 30° W. and dipping 40° W., and the Jane striking N. 40°–60° E., and dipping steeply eastward (see Fig. 5). The actual intersection of the veins has not been found. The Capps was worked to a maximum depth of 130 feet in the Bissell shaft. The filling of the vein is quartz. Its thickness, as explored in the mine workings, was not less than 20 feet; definite walls were only found at a few points. The pay-ore was not uniformly distributed in the quartz, but generally occurred in layers. Four ore-shoots have been explored. The brown ores extend to a depth of 130 feet. The sulphurets are pyrite, with some chalcopyrite. The past production of the Capps has been estimated at over $1,250,000.

In the summer of 1895, Mr. Wilkes, the owner of the Capps, made at his test plant in Charlotte, a trial run of 50 tons of Capps ore (sulphurets) from the old dumps, and the result of this milling and chlorination test was a yield of $27 per ton.

Between January and April, 1895, four diamond drill-holes (1-inch

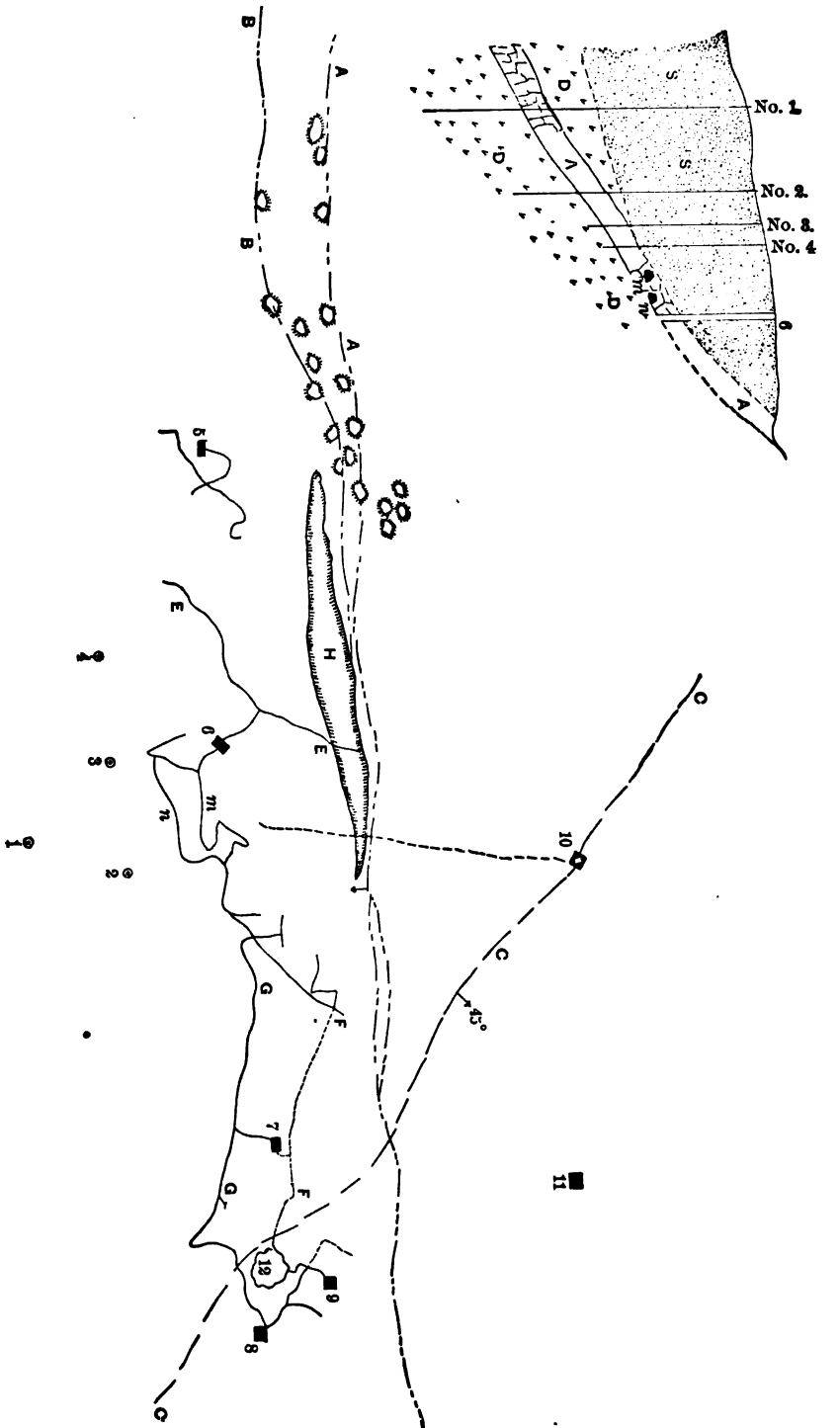

Fig. 5. Plan of Capps Mine. Scale, 1 inch=200 feet.

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core) were bored on the Capps vein. Fig. 5 shows their position relative to the mine-workings in plan, as well as a vertical section of the ground which they explored.

A, Capps vein; B, parallel vein; C, Jane vein; D, diorite; E, 90-foot level; F, 78-foot level; G, 130-foot level; H, open cut; S, saprolites; m, drift; n, drift; 1, borehole, 350 feet deep; 2, borehole, 250 feet deep; 3, borehole, 220 feet deep; 4, borehole, 200 feet deep; 5, Penman shaft, 80 feet deep; 6, Bissell shaft, 125 feet deep; 7, Mauney shaft, 130 feet deep; 8, Baldwin shaft, 120 feet deep; 9, Gooch shaft, 10, Old shaft; 11, Isabella shaft, 160 feet deep.

The Capps vein was penetrated by each borehole, and showed a regular thickness of about 20 feet, with walls of fine- and coarse-grained diorite, at times porphyritic. The dip is quite constant, about 30° S.W. The vein-matter is quartz, averaging $6 to $7 per ton, as shown by assays of the drill cores. The drill-holes are certainly very satisfactory, in so far as they prove the continuity in depth, and regularity in thickness of the Capps vein; and, on a large body of ore, such as this is, the assays of the drill cores are of value as showing at least the presence of mineable ores.

The McGinn mine comprises the Jane vein, worked to a depth of 160 feet in the Isabella shaft, and a cross-vein on the northern extension of the Jane, known as the Copper vein, which has been worked to the depth of 110 feet as a copper mine.

The Ferris mine is situated 5½ miles northeast of Charlotte. The character of the vein-matter is milky quartz, carrying free gold and pyrite. It lies with the schists, striking N. 25° E. and dipping 70° N.W. The quartz is broken up into stringers, the widest solid portion being 12 inches. The vein, as a whole, is stated to vary from 2½ to 5 feet in thickness. In the fall of 1894 the mine was being worked by two shafts, respectively 56 and 95 feet deep. The ore was treated in a Chilean mill of 3 tons capacity. It is stated that the concentrates assay from $45 to $60 per ton.

MINES IN GASTON COUNTY.

Among the mines of this county are the Oliver and Farrar (12 miles northwest of Charlotte), the former being situated on the Catawba river near the "big bend," and reported to have been worked by one of the early German settlers prior to the Revolutionary war; the Rhyne and Derr (17 miles west of Charlotte), the Duffie and Robinson (16 miles west of Charlotte), the Smith and Sam Beattie (13 miles west of Charlotte), the McLean (15 miles southwest of Charlotte), the Long Creek and the Kings Mountain.

The Long Creek mine is situated in the northern part of the county,

THE THIRTY-STAMP MILL AT THE CATAWBA MINE, KING'S MOUNTAIN.

about 6 miles northwest of Dallas. The property contains 600 acres. The country-rock is chloritic schist, striking northeast and dipping 85° northwest. There are three veins lying with the schists, and consisting of lenticular quartz-bodies. The Asbury vein was 6 to 8 feet thick, and contained rich ore-shoots carrying sulphurets (pyrite, chalcopyrite, galena, blende and mispickel). A 10-stamp mill was running here in 1891, and in the following year a Crawford mill was put in, which was, however, soon abandoned, and the mine has since been practically idle.

The Kings Mountain (Catawba) mine is situated about 1½ miles south of Kings Mountain, a station on the Southern Railroad, in the southwestern corner of the county. The country-rock is mica-schist, striking N. 50° E. and dipping 70° N.W., intercalated with lenticular masses of siliceous magnesian limestone. These rocks appear to be of sedimentary origin. The ore-bodies consist of large lenticular chimneys or shoots of this limestone, containing auriferous quartz and sulphurets (pyrite, chalcopyrite and galena up to 3 per cent.). Tellurides also occur in very small quantity. Five such lenses have been opened in the mine.

In length these lenses reach about 100 feet and in thickness 20 feet, being separated by a black graphitic slate carrying coarse pyrite, which is, however, barren. The mine has been opened to a depth of 320 feet. At the time of our visit 40 tons of ore were being raised per 24 hours by a total force of 20 men. (Cost of mine labor, 75 to 85 cents per day). The rock is very tough, and 60 per cent. dynamite is used for blasting. The mill house is equipped with a well-constructed 30-stamp mill built by the Mecklenburg Iron Works, of Charlotte (Plate VII), and 5 Frue vanners (6x14 feet). Weight of stamp, 750 pounds. Twenty stamps were dropping 71 times per minute—the height of drop being 5 inches. The ore was crushed through a 40-mesh brass wire screen. The mill yield is stated to be $3 per ton, with a loss of $3 in tailings. Great difficulty was found in saving free gold, and the quicksilver gave trouble by flouring; this is ascribed to the graphitic slates which occur with the ore. The concentrates run $35 to $40. The total cost of mining and milling is $1.75. Two men are employed in the mill at $1 per day. The cost of wood is $1.35 per cord.

A plant for washing the surface brown ores and saprolites is situated at the mine, and was in successful operation until lately. It consists of 2 sets of 12-foot log-washers. The slimes flowed over amalgamated copper plates (12 feet by 5 feet), while the material carried up in the washer was screened through a ½-inch perforated revolving screen, and then through a 20-mesh brass wire revolving screen, from whence it passed over copper amalgamating plates. The coarse material was taken to the stamp-mill. A large proportion of the

gold remained in the log-washers; much was caught on the plates below the fine screens; and the smallest amount, which was all fine gold, was caught on the slime plates. Trouble was also experienced here by the flouring of the quicksilver. The bottom land lying directly to the east of the mine is being worked in shallow pits by tributors, who wash the grit and soft bed-rock slates in sluice boxes. Panning showed up very well here, and the ground might pay for hydraulic working on a large scale.

MINES IN LINCOLN, CATAWBA, DAVIE, ALEXANDER AND YADKIN COUNTIES.

Gold has been found in these counties in isolated localities; but with few exceptions no mining work of any consequence has been done.

The Dixon mine, in Yadkin county, is a new discovery (1895). The vein is reported to be several feet in thickness, of high-grade sugary quartz, containing some copper. Only prospecting work has been carried on. The developments consist of a 40-foot shaft and 140 feet of levels on the vein. A hundred tons of ore taken out had a reported value of $5 per ton.

THE SOUTH MOUNTAIN BELT.

MINES IN CALDWELL COUNTY.

The Miller, Scott Hill, Pax Hill and Baker mines are situated within a distance of 1½ miles from Johns river, and near the southwestern boundary line of the county. The mines are located in each instance in close proximity to a wide dike of olivine diabase, which strikes through the country for many miles in a direction N. 20° W.

The Miller, Scott Hill, and Pax Hill veins strike N. 50°–60° E. and dip N.W.; as far as observed they are from 8 to 12 inches in thickness.

At the Baker mine the strike of the veins is N. 35°–45° W., and the dip is 60°–70° N.E. The thickness is from 2 to 5 feet; the ores contain auriferous and argentiferous galena.

The Bee Mountain mine is about 4 miles northeast of the Baker mine, and the ores contain zinc-blende, galena and chalcopyrite.

MINES IN BURKE, McDOWELL AND RUTHERFORD COUNTIES.

By far the greater proportion of gold coming from these counties has been won by placer mining. With few exceptions, the quartz-veins are too narrow to justify deep mining. But even in the cases where the veins are of sufficient width, mining operations have been very spasmodic and of limited extent. Placer mining on a larger scale has been carried on during the past years only at a few points. Such

are the Mills property and Hancock mines in Burke; Cane creek, Brackettown, Huntsville and Vein Mountain in McDowell, and Golden Valley in Rutherford county.

The Mills place is fully described elsewhere (p. 95), and will serve as a type for the other mines of the district. Petty mining is almost constantly in progress in the above counties, as well as in certain parts of Cleveland and Polk counties to the south.

Of the quartz-mines, those worthy of mention are the Idler, Elwood and Vein Mountain.

The IDLER (Alta or Monarch) mine is situated about 5 miles north of Rutherfordton, in Rutherford county. As many as 13 parallel quartz-veins have been explored here within a distance of ½ mile. The country is gneiss, striking about N. 60° W., and dipping 25° to 30° N.E. The veins strike N. 65° E. The vein-matter is quartz, containing sulphurets (pyrite and some chalcopyrite). The Alta vein has been explored to the depth of 105 feet; its thickness is from 10 to 22 inches; the ore is stated to yield $10 per ton. The mine has been worked in a desultory way, but is now under water.

The ELWOOD mine is 1½ miles southwest of the Idler. The character of the country and of the veins is similar to that of the Idler. The ore is reported to yield $5 in free gold. The mine was last operated in 1893.

The VEIN MOUNTAIN mine is situated in McDowell county on the Second Broad river. A series of as many as 33 parallel auriferous quartz-veins crosses Vein mountain in a belt not over ¼ of a mile wide. The principal and largest one of these is the Nichols, which has been prospected in four shafts within a distance of 1200 feet, the deepest one being 117 feet. The strike of the vein is N. 80° E., and the dip 75° N.W. Its thickness is reported to vary from a few inches to 3 feet. The quartz is mineralized with pyrite, galena, blende and chalcopyrite. The value of the ores varies from $2.50 to $70 per ton. There is a 10-stamp mill on the property, but it has never been operated on any regular output.

At BRACKETTOWN, 5 miles northeast of Vein mountain, an expensive shaft has been sunk to a depth of 126 feet, on a parallel series of several narrow (1 to 6-inch) quartz-veins, with the fallacious hope that these would come together in depth. It is needless to say that these small veins will not justify working alone unless the intervening country (gneiss) is found to contain auriferous sulphurets of sufficient richness to make large bodies of low-grade ores.

An isolated belt of gold-bearing rocks has been mentioned in Henderson county, N. C. (see p. 20). The only mine situated here is the BOYLSTON, 12 miles west of Hendersonville. The country-rocks are

fine-grained, mica- and hornblende-gneisses and schists, in part much crumpled, striking N. 20°–30° E., and dipping 35°–60° N.W. The quartz-veins coincide, more or less, with the strike of the schists. The mine has been opened by a series of shallow shafts and short drifts on one of these veins, which is from 3 to 4 feet in thickness, with a pay-streak of 1 to 3 inches on the hanging; it is accompanied, in places, by a granitic dike. The ores are reported to average about $4 per ton (assay value); sulphurets occur, chiefly pyrite and some chalcopyrite. A 10-stamp mill (in bad repair) stands on the property. It has not been in use since 1889.

MINES IN THE MOUNTAIN COUNTIES.

In the northwestern corner of North Carolina, the copper ores of some of the Ashe county mines, and some small galena-bearing veins in Watauga and Wilkes counties, are auriferous.

In the southwestern corner of the State (in Jackson, Swain, and Cherokee counties) some placer-mining operations have been carried on from time to time, notably in Georgetown valley, Jackson county, and about the headwaters and other tributaries of Valley river, in Cherokee county, but nowhere successfully on a very large scale.

Gold is also stated to occur in Macon county, and this may be a northern extension of the Georgia belt (see p. 21).

In Horse Cove, Macon county, the Ammons Branch mine has recently been explored, with the showing of a 10-inch quartz-vein, from which very rich specimens have been taken.

In the southern part of Clay county the Warne mine is situated at the northeastern extremity of a small belt of auriferous quartz-veins which extends southwesterly into Towne county, Ga. (For description see p. 84).

CHAPTER IV.

DISTRIBUTION OF GOLD MINES IN THE SOUTH APPALACHIAN REGION OTHER THAN IN NORTH CAROLINA, WITH MINING NOTES.[1]

GOLD MINES IN MARYLAND.

The gold mines are situated within the belt of crystalline rocks extending from Washington to Great Falls, on the Potomac river, in Montgomery county, and also in the central and northern part of this county. Geologically, they are included in the Virginia belt (see p. 13).

The greatest development has been in the vicinity of Great Falls, about 15 miles west of Washington. Among the principal mines in this region are the Maryland, Montgomery, Harrison (or Sawyer), Irma, Huddleston, and Allerton-Ream, situated in a belt from 7 to 8 miles in width.[2] The greatest development was during the years 1888-93, in which time the various properties were worked. Since that time operations have been carried on in a limited way at the Allerton-Ream, Harrison, Miller and Bethesda.

During the winter and early spring of 1895 a considerable amount of exploratory work was carried on at the Bethesda mine, 7 miles northwest of Washington, by the Bethesda Mining Company. Some $20,000 to $30,000 had formerly been taken from a rich chimney in a 6-foot quartz-vein at this mine. The old shaft was continued to a depth of 102 feet, and the ore-shoot found to pinch out. Assays from the lower end of the chimney ran about $4 per ton. There are no sulphurets to speak of in the ore at this depth. The country-rock (micaceous schist) is slightly auriferous in places. It is stated that large areas of the saprolites will yield 18 cents per cubic yard. Sufficient water-supply for hydraulicking or sluicing is difficult to obtain.

GOLD MINES IN VIRGINIA.

The principal gold region of this State is comprised in the Virginia belt (see p. 13). A small, isolated area of placer deposits is situated on the west side of the Blue Ridge in Montgomery and Floyd counties.

[1] Unless otherwise stated, the mines are not at present working. The values of the ores are not given on our authority; the same is true of the dimensions of the ore bodies in abandoned mines, and in such as could not be examined.

[2] The best description of these mines has been given by Mr. S. F. Emmons, in a paper entitled "Notes on the Gold-Deposits of Montgomery County, Maryland," *Trans. Am. Inst. Min. Engs.*, xviii, 1890, pp. 391 to 412.

So far as is known, none of the Virginia mines are at present working on an actively producing scale, although considerable prospecting is in progress and apparent preparations for mining are being made.

The mines of Fauquier, Stafford, Culpeper, Orange and Spottsylvania counties are grouped around the junction of the Rappahannock and Rapidan rivers in a belt some 15 miles wide.

MINES IN FAUQUIER COUNTY.

The Franklin, Wycoff and Leopold mines are situated in the southern part of the county near Morrisville.

MINES IN STAFFORD COUNTY.

The principal localities are in the western part of the county near the Rappahannock river. The EAGLE mine, situated 12 miles northwest of Fredericksburg, was worked by the Rappahannock Gold Mining Company in 1894; greatest depth, 250 feet; length of workings, 600 feet.

The MONROE mine adjoins the Eagle on the northwest, and the Lee mine is situated in the same vicinity.

The RATTLESNAKE mine adjoins the Eagle on the northwest. It was worked as a gulch placer; large amounts of nuggets are reported, weighing from ½ to 5 dwts.; some as high as 125 dwts.

MINES IN CULPEPER COUNTY.

The CULPEPER mine is situated 18 miles west of Fredericksburg on the Rapidan river. Prof. Silliman (in a report made in 1836) stated the average value of this ore to be $25 per ton, and the mining and milling expenses at $7 per ton. Other mines in the district are the Richardville and the Ellis.

The Powhatan Land and Mining Company operated a mine in this county in 1894, treating the ore in Crawford mills and a ten-stamp mill (Fraser and Chalmers' make) in connection with Frue vanners.

MINES IN SPOTTSYLVANIA COUNTY.

The oldest mines worked in this county were those operated by the United States Mining Company near the Rappahannock river in the extreme northwest corner of the county. A description of the method of milling at these mines in 1835 is given on p. 33. At that time a 2-foot vein was operated by adits and several shafts, the deepest of which was 80 feet. The value of the ore is given in this early report at $25 per ton, and the cost of milling at 80 cents per ton. Other old mines near this property are the Marshall and the Gardiner.

In the central portion of the county there is a group of mines, most prominent among which is the Whitehall,[1] which was in active operation as late as 1884. Other properties in this group are the Kiggins, Johnston, Pullian and Grindstone Hill mines.

Still farther south are the Mitchell and the Goodwin mines. They are located on Pigeon run, along which considerable placer-work was done in the earlier days. Both have been worked within the past twelve years, but no paying vein was developed.

MINES IN ORANGE COUNTY.

The gold mines of this county are situated in the northeast corner near the Rapidan river. The most prominent one among them is the Vaucluse, which was discovered and opened in 1832. A description of the milling practice at this mine in 1847 is given on p. 34. Other mines in the vicinity are the Orange Grove, Greenwood and Melville.

MINES IN LOUISA COUNTY.

The gold-bearing rocks traverse the central portion of the county in a southwesterly direction, forming a narrow belt but a few miles in width. In this belt, near the centre of the county, and from 2 to 6 miles northeast of Mineral City (Tolersville), are the LOUISA COUNTY PYRITE MINES. These large bodies of sulphurets, occurring in lenses with a maximum thickness of 60 feet, and developed to a depth of over 600 feet, are probably of contemporaneous origin with the gold-veins. They show the same strike (N. 30° E.), dip (60° S.E.) and pitch of shoots or ore lenses (45° N.E.) as the quartz-veins in the vicinity. Traces of gold are found in the pyrite deposits, and small gold-bearing quartz-veins have been encountered in the mines. We quote from a letter written by Mr. W. H. Adams, manager of the Arminius Pyrite Mines, Mineral City, to whose kindness we are much indebted:

"It is true that in the pyrite vein, as now opened, there are traces of gold and silver, but I do not think the average so high as $1.00 per ton, and have found that gold carries only in certain lines, and that nearly all the vein matter is barren. There are, in all of the properties, easily traceable quartz-veins in the hanging- and foot-slates, which are gold-bearing to the extent of $4.00 to $15.00 per ton, but these veins are always narrow—about as you saw them in our No. 3 shaft (3 to 7 inches). They are, however, persistent, and I have no doubt that chimneys are to be found at points of contact of the veins and dikes, which chimneys will be found to be the source of much of the gold so prevalent in the streams of the neighborhood."

The scope of this report will not permit a detailed description of these interesting pyrite deposits or the methods of mining and concentration

[1] See *Am. Jour. Sci.*, i, xxxii, 1837, p. 101.

pursued here.[1] It may, however, be of value to give the cost of labor at these mines, as this would apply equally to auriferous mining. The daily wages paid are:

Carpenters	$1.25 to $1.75
Engineers	1.40
Blacksmiths	1.30 to 1.75
Drill-runners	1.35
Helpers	1.20
General labor (under ground)	1.00
" " (above ground)	0.90 to 1.00

The TINDER FLATS placer deposits[2] are situated at the northern end of the pyrite bodies on both banks of North Contrary creek.

This bottom was perhaps the best known and most productive source of placer-gold in the early days of Virginia gold-mining.

At present the problem is one of reworking shallow placer bottoms on a large scale, and at the time of our visit in 1895, Mr. W. H. Case, of Charlotte, N. C., was testing the ground with this object in view. Water under natural head cannot be obtained here, the surrounding country being a but slightly indented pene-plain it would probably have to be pumped from the North Anna river.

One-half mile southwest of the Arminius pyrite mine, on the same line of strike, is the WALTON gold mine. This mine has produced some very rich ore from a shoot or chimney developed to a depth of 150 feet. The property has been tied up in litigation for the past twelve years.

Near Mineral City (Tolersville) a vein, known as the FISHER LODE, striking parallel to the pyrite veins and about 2 miles to the east of them, has been opened by the Harris, Luce, Slate Hill, Louisa and Warren Hill mines. Two of these, the Luce and Slate Hill, were in operation at the time of our visit.

The LUCE mine had been developed to a depth of 200 feet, and the total length of drifting on the vein is over 1000 feet. The thickness of this vein is from 3 to 8 feet. The mine is equipped with a 20-stamp, hand-feed mill (Fraser and Chalmers' build).

The SLATE HILL mine was first opened in 1850, and for a time was extensively worked. It is the southwest extension of the Luce, which formerly constituted a portion of the property. Two veins are developed to a depth of 150 feet. In a report made in 1853, the average value of the ore is given at $4 per ton, and the cost of mining and milling at $1.40 per ton. The present company began operations in March, 1895. A Huntington mill has been erected, and the mine was being developed in the lower levels at the time of our visit.

[1] For a description of the deposits, see "Origin of the Iron Pyrites Deposits in Louisa County, Virginia," by Frank L. Nason; *Eng. and Min. Jour.*, lvii, 1894, pp. 414-16.

[2] See *Am. Jour. Sci.*, i, xxxii, 1837, pp. 101, 110.

MINES IN FLUVANNA AND GOOCHLAND COUNTIES.[1]

The same narrow belts traverse the boundary of Goochland and Fluvanna counties, crossing the James river at Bremo Bluffs into Buckingham county. No work but petty placer-mining and more or less active prospecting is carried on in these counties at present, although from 1830 to 1860 this region was the field of extensive operations.

Among the well known properties are the Tellurium, the Bowles, the Payne, the Page, the Hughes, the Moss, the Fisher, the Busby, the Tagus, the Gilmore, the Collins, Marks, Eades, Big Bird and the Belzora.

The TELLURIUM mine, embracing a property of 644 acres, lies partly in Fluvanna and partly in Goochland county, 6 miles from Columbia, and is at present owned by the Columbia Gold Mining Company. It was discovered in 1834 by George Fisher, and is reported to have yielded $1,000,000 during its various periods of activity. It was last operated in 1886. Three principal parallel veins, the "Sandstone," "Middle" and "Little," traverse the property in a southwesterly direction for a distance of about half a mile. None of the workings have extended below a depth of 60 feet.

The BOWLES mine adjoins the Tellurium, and the Payne mine is in the same vicinity.

Lying partly in Fluvanna and partly in Goochland county, and within ½ mile of the Tellurium and Bowles mines are the Fisher, the Moss and the Busby mines, all on the same lode.

The FISHER mine was opened in 1860 by James Fisher. The main developments consist of a 40-foot shaft with 175 feet of levels. The vein is narrow, from 3 to 15 inches, and the ore is stated to carry from $25 to $300 per ton.

The Moss mine is one mile northeast of the Fisher. It was discovered in 1835 by John Moss. It has been worked to a depth of 65 feet, and the vein, which is 2 feet wide in places, carries reported values of $15 to $65 per ton.

The BUSBY mine is one-half mile northeast of the Moss. Prof. Silliman, in an early report, gives ore values of $160 per ton from here. The work has been altogether of a superficial nature.

The PAGE mine is situated ½ mile west of Wilmington on Long Island creek in Fluvanna county. Work was begun on the quartz-veins in 1856, when an 8-stamp mill was erected. Considerable prospecting work has been carried on lately.

The HUGHES mine is 5 miles from Bremo Bluffs in Fluvanna county.

[1] We beg to acknowledge our indebtedness to Messrs. Wm. Bugbee and Scott Thurston of Palmyra, Va., for information concerning the mines of these counties.

It was opened in 1836. The last work was done about 4 years ago, when a 60-foot shaft was sunk, but without encouraging results.

The BELZORA mine is 7 miles from Columbia in Goochland county. It was discovered in 1832, and was worked by surface washing until 1849, and after that the veins were opened. The Marks, Collins, Eades and Big Bird mines adjoin the Belzora.

MINES IN BUCKINGHAM COUNTY.

This is the most southwesterly county of the Virginia gold belt in which mines have been actively operated. The occurrence of gold has, however, been reported still farther to the southwest, in Appomattox, Prince Edwards, Charlotte, and Halifax counties.

The BOOKER mine, near Whitehall Station, was worked prior to 1860 by an English company. The deepest shaft is 110 feet. The ore was crushed in a Howland mill and yielded $13 per ton.

Another English company operated the London mine, seven miles north of the Booker, for a number of years. Other mines of equal importance in their day are the Garnett and Mosely (3 miles west of Willis mountain), the Buckingham, the Morton, the Morrow, the Duncan, the Ford, and the Lightfoot.

MINES IN FLOYD AND MONTGOMERY COUNTIES.

A small placer-mining field was opened here (on the west side of the Blue Ridge) in 1879, along Brush and Laurel creeks and other small streams running from Pilot mountain. The area embraces about 80 square miles.

The Walters and Gardner mine in Montgomery county was operated in 1893.

Gold also occurs it Patrick, Carroll and Grayson counties, but probably only to a very limited extent, associated with copper ores.

GOLD MINES IN SOUTH CAROLINA.

The present gold output of South Carolina is derived almost entirely from the Haile mine.

To show the extent and distribution of the gold-mining industry in South Carolina before the war, the following table comprising the working mines in 1859 is given:[1]

Chesterfield and Lancaster counties	21	working	mines.
Spartanburg, Union and York counties	19	"	"
Abbeville and Edgefield counties	10	"	"
Greenville and Pickens counties	8	"	placers.
Total in State	58		

[1] *South Carolina. Resources, etc.*, published by the State Board of Agriculture, Charleston, 1883, p. 134.

Some of these were probably minor operations, as Lieber[1] in his reports, made a few years earlier, complained of the lack of interest taken in the South Carolina gold mines.

CAROLINA BELT.

CHESTERFIELD COUNTY.—The Brewer mine is the main point of interest in this county. It is fully described on p. 144.

In the same neighborhood are the old Kirkley, Leach and McInnis mines. Some gravel mining has been done near the northern boundary of this county.

LANCASTER COUNTY.—The Haile mine is fully described on p. 125. The Funderburk, 8 miles northeast of the Haile, and of the same character, was worked as late as 1887. The Clyburne property is situated 1½ miles southwest of the Haile. Some tributing is done here with rockers, on saprolite and gulch deposits. Adjoining this on the southwest is the Gay mine, which shows ore-bodies of the Haile type, but is little developed. The most southerly occurrence of gold in this district is at the Williams mine, 7 miles southwest of the Haile.

YORK COUNTY.—There is no active work at present in this county. Among the older mines of this district are the Wilson, Wallace and Palmetto.

UNION COUNTY.—About 3 miles south of Glen Springs are the West and the Thomson mines. Mr. Becker describes the veins as quartz lenses similar to the Dahlonega type, interlaminated with mica- and hornblende-schists. The Thomson mine was operated during the summer of 1895 on a small scale by the Dahlonega method of mining and milling.

ABBEVILLE AND EDGEFIELD COUNTIES.—Little information could be obtained regarding the mines of this district. The deposits are probably closely connected with, and of the same nature as those in McDuffie, Warren and Columbia counties, Ga. The Dorn mine, situated at the lower end of the Abbeville district, was opened in 1852. In the first year of its operation over $300,000 are said to have been taken from a rich pocket in this mine; a yield of $100 per ton was considered a poor one. The rich pockets were, however, soon exhausted; and the mine was abandoned until 1866, when it was reworked for a short time with some success, as reported.

SOUTH MOUNTAIN BELT.

SPARTANBURG, GREENVILLE AND PICKENS COUNTIES.—The gold district in these three Piedmont counties is probably a continuation of the

[1] For a full discussion of the occurrence of gold and a description of the older mines in South Carolina, see Tuomey (M.), *Report on the Geology of South Carolina*, 1848; and Lieber (O. M.), *Reports on the Survey of S. C.*, 1856, 1857, 1858 and 1859.

South Mountain belt in North Carolina (page 68), and, as in that district, the gold produced has been obtained almost entirely from placer-deposits. The present operations are purely of a desultory character. Among the more extensive deposits might be mentioned those of Wolfe creek and Tiger river, located on the boundary between Spartanburg and Greenville counties at the foot of Hogback mountain. The gold in these bottoms is derived from small quartz-veins having the same strike and dip, and being in other respects similar to those of the South Mountain district in North Carolina. The gravel in the bottom is from a few inches to 5 feet in thickness. It consists of white, saccharoidal and glassy, barren quartz. In 1892 the Wolfe creek bottom was worked by the Wolfe and Tiger Mining Company, with a 2-inch nozzle giant, supplied with 45 feet head of water by a 4-mile ditch.

Other mining properties in this vicinity are the Hammett, Knott, Golden Gate, Thompson, Hale and West Springs.

GOLD MINES IN GEORGIA.[1]

MINES IN RABUN COUNTY.

Some work has been done at the Smith mine near Burton, and at the Moore Girls' mine, 12 miles northwest of Clayton.

MINES IN HABERSHAM COUNTY.

Practically no work of importance has been done in this county, excepting perhaps some development work a few miles northeast of Clarkesville.

MINES IN WHITE COUNTY.

The chief mining district is located in the picturesque Nacoochee valley and its vicinity. Among the many Indian traditions of this neighborhood is that of extensive gold mining by the aborigines, but absolute proof of this is wanting.

The LUMSDEN mine is situated about 2 miles north of the Nacoochee valley on Bean creek. Several rich quartz-stringers were being worked in 1895 by tributors, using a combination of hydraulic and dry mining, the hard ore being hauled ¼ mile to a wooden 10-stamp mill, driven by a 20-foot over-shot water-wheel. Five hands are stated to extract 70 to 80 dwts. per week by this crude method.

The JARRET mine adjoins the Lumsden on the south; a 20-stamp-mill was operated here for some time by Mr. Childs, of Athens, Ga.,

[1] For a more complete statement concerning gold mines and mining in Georgia see *Bulletin No. 2 of the Georgia Geological Survey, Atlanta, Ga.*

using the Dahlonega method of sluicing and milling (see p. 107). It has been idle for the past eight or nine years.

The Yonah Land and Mining Company controls some 4800 acres of mining property situated mainly along the watershed of Dukes creek. This property is a consolidation of what was formerly known as the TONTON, the MERCER and the BUTT mines. The company has pursued extensive vein explorations on their land under the direction of Mr. E. T. Whatley. This prospecting work has disclosed a large number of auriferous quartz-veins, which have a general strike of N. 20° E. and a dip of about 85° S.E., while the dip of the country-rock is steeply to the N.W. Although of low grade ($3 to $7 per ton) and of small width (6 inches to 3 feet), some of these veins might, under close management, be mined and milled at a profit. The producing operations of this company are confined to placer work with hydraulic elevator in the bottom land of Dukes creek. The elevator used and the method of work in the pits is similar to that employed by the Chestatee Company (see p. 101). A 65-foot head of water is obtained from a 7-mile ditch line. The gravel bed averages about 3 feet in thickness, covered by 6 inches of peat and clay, and above this about 6 feet of soil overlay. The gold consists, to a large extent, of extremely rounded and waterworn nuggets, often aggregated in pockets, from one of which $1500 is reported to have been taken in one day.

The LOUD mine, situated near Pleasant Retreat P. O., and about 11 miles east of Dahlonega, is one of the famous placers of the district, and has produced a large amount of remarkably well crystallized and wiry nugget gold. It has been known as one of the most extensive and richest deposits in the Southern States. For the past few years the work has been confined to hydraulicking old gravel piles. Water, under a 75-foot head, is leased from the Hand-Barlow Company of Dahlonega and is supplied by a ditch 25 miles in length. Extensive cuts in the saprolites have been made here.

Other properties of importance in White county are the Longstreet placer, 2½ miles northwest of Cleveland, the Nacoochee Hills Gold Mining Company, the Martin Mining Company, the St. George property (also known as the Dean Mine), the Plattsburg (or Chattahoochee) Gold Mining and Milling Company, etc.

Besides these there are quite a number of petty operators, some washing gravel in sluice boxes, others mining rich, narrow seams in the saprolite and "beating" the ore in wooden stamp-mills, as, for instance, at the Thompson mine near the Yonah Land Company's property, where the mining operations were formerly carried on by a mother and son, the latter digging the quartz and carrying it on his back to the mill, while his mother attended to the beating.

MINES IN HALL COUNTY.

But little active work has been in progress for a number of years. The principal properties are the Potosi, 12 miles northeast of Gainesville, the Currahee, 6 miles northeast of Gainesville, the Elrod, the Merrick, the Mammoth and the Glades. The Currahee mine is equipped with a 20-stamp mill and a roasting furnace. The ore is quartz, containing pyrite and galena. A set of rolls and a cyanide plant are now being erected at this mine.

MINES IN LUMPKIN COUNTY.

The principal mining operations are in the vicinity of DAHLONEGA, extending from the Yahoola river, about 1 mile northeast of the town, in a continuous belt nearly 4 miles in width to the mining village of Auraria (Kunckelsville), a total length of about 6 miles. A general description of this belt and the method of mining and milling (which bears the name of the Dahlonega or Georgia method) pursued here is given on page 107.

This is by all means the most important mining district in Georgia. In 1838 a United States mint was established in Dahlonega, which continued in active operation until 1861, during which time $6,106,569 were coined. The nearest railroad point to Dahlonega is Gainesville (Southern R. R.), 20 miles to the southeast. A connecting branch between these two points is looked for in the near future, and will greatly benefit the mining interests of the district.

The following is a list of the prominent mines and their crushing equipment: Mary Henry (or Murray) (5 stamps); Hand (20 stamps); Singleton (10 stamps); Yahoola (20 stamps); Stanley (10 stamps); Findley (40 stamps); Preacher (10 stamps); Hedwig (40 stamps); Josephine (20 stamps); Lockhart (20 stamps); Barlow (40 stamps); Ralston (20 stamps); Turkey Hill (10 stamps); Woodward (5 stamps); Ivy (60 stamps); Calhoun (40 stamps); Garnet (20 stamps); Bigley (20 stamps); Fish Trap (20 stamps); Bast (10 stamps); Siloam (10 stamps); Lawrence (10 stamps); Horner (5 stamps); Betz (1 Huntington mill). In the summer and fall of 1896 240 stamps were being operated at the Findley, Hand, Yahoola, Murray, Lockhart, Singleton, Woodward, Preacher, Turkey Hill, Ralston, Barlow and Hedwig mines.

Of late years more attention is being paid to the deep-mining of hard ore in distinction to the usual method in this district of sluicing the soft saprolites. Thus, at the Lockhart mine, quartz from underground stopes is treated in a 20-stamp mill (for description of which see p. 115).

The special operations of the Chestatee Company, and of the dredge boats on the Chestatee river, are described on pages 101, 106.

Among the mines of this district there are some that are operated by lessees, and in those cases the usual royalty is 25 per cent. for properties on which a mill and water-power are furnished, and 10 per cent. where these are absent.

MINES IN DAWSON COUNTY.

At present no active work of any prominence is prosecuted. Among the mines formerly extensively operated by the Dahlonega method may be mentioned the Cincinnati Consolidated, the Etowah, the Kin-Mori and the McGuire, all situated in the vicinity of Dawsonville, the county seat.

At the Kin-Mori a ditch 34 miles in length, delivering 600 to 700 inches at a pressure of 286 feet, was completed in 1883, and placer-mining on an extensive scale was carried on in connection with a Hendy gravel elevator. A 30-stamp mill was erected during the winter of 1884-85. The mine has been idle since 1888.

MINES IN FORSYTHE COUNTY.

No mines of importance have been developed, the gold output having been derived almost solely from small placer-diggings. The Dr. Charles property, which is 6 miles southwest of Dawsonville, and not far from the Cherokee county line, has been prospected to some extent. The quartz-veins carry arsenical pyrites from the grass roots down, and very little ordinary pyrites. There is a 10-stamp mill at this mine.

Other properties that might warrant attention are the Little, Settles, Collins, Sawnee Mt., Parks, and Fowler.

MINES IN GWINNETT COUNTY.

The Piedmont mine, 2 miles northeast of Buford, has been worked in a small way until recently. The vein-quartz carries pyrite, galena, and free gold.

The Shelby mine is 4 miles west of Buford. It is equipped with a 5-stamp mill. The quartz-vein is 2 feet in width, and is stated to carry values approximating $6 per ton. The Simmons property adjoins the Shelby on the east.

MINES IN CHEROKEE COUNTY.

At Creighton, near the eastern boundary of this county, is located the Creighton (Franklin) mine, which, together with the Haile mine of South Carolina, and some smaller mines in North Carolina, shows the brighter side of Southern gold-mining. It is a continuously and systematically worked, dividend-paying property (for description

see p. 121). Stimulated by the success of this mine, developments are being pushed on several other properties in this county, mainly along the approximate strike of the Franklin vein. The properties extend from a point about 3 miles north of the Creighton, in a more or less continuous line to the Sixes, Wilkinson, Cherokee (10 stamps), Georgiana, Cox and Worley mines in the southwestern portion of the county. Near the center of this belt, south of the Creighton, the Chester (formerly Latham) and the Strickland properties have been prospected.

MINES IN BARTON, COBB, PAULDING AND DOUGLAS COUNTIES.

The same auriferous belt, described above as occurring in Cherokee county, extends through a portion of Barton, Cobb and Paulding counties. In the latter county a high-grade quartz-vein has been opened up in the Yorkville mines.

In Douglas county, lenses of auriferous quartz have been explored to some extent in former years, but no active mining is carried on at present.

The MINERAL HILL mine in this county has been developed by a double-compartment shaft 120 feet in depth, sunk on the vein. At the 80-foot level the width of the ore-body is estimated to be 15 feet. The ore is rich in sulphurets (pyrite and chalcopyrite), and is stated to have an average value of $8 per ton.

MINES IN CARROLL COUNTY.

The principal mining district is in the vicinity of Villa Rica, where prospecting and development work has been quite active during recent years. The principal properties are the Clopton mine, operated by the Boston Kennesaw Mining Company; the Mineral Farm mine, 3½ miles northwest from Villa Rica; the Pine Mountain mine, operated by the Southern States Exploration and Financial Syndicate, L't'd.

MINES IN HARALSON COUNTY.

Several mines have been opened in the southwestern portion of this county, lying in the belt which, to the southwest, is more extensively developed near Arbacoochee, Ala. The most important of these is the ROYAL (formerly known as the Camille) mine, 2½ miles southwest of Tallapoosa.

In past years the soft, semi-crystalline slates were sluiced, the loose free gold saved in the sluice boxes, the quartz milled, and the gold saved by amalgamation. In the washed-off portion, hundreds of quartz-stringers, from the size of a knife blade to 5, 6 and more feet in thickness, can be seen striking almost due east and west.

In 1887 a large amount of money was spent in developing the mine and in erecting a 20-stamp mill (Fraser and Chalmers), with 8 Frue vanners. A double-compartment inclined shaft was sunk to a depth of 186 feet. The ore was milled at the rate of 4 tons per stamp head. But little free gold was saved, the loss in the sulphurets being great, and after a short run the work was abandoned as unprofitable.

In December, 1895, Capt. A. Thies, of the Haile mine, S. C., made a thorough examination of this property, which resulted in reworking the mine and the erection of a chlorination plant.

The outcrop of the main vein, on which the 186-foot shaft is sunk, is exposed for 600 feet west of the shaft. The width of the ore-body is stated to be 6 feet. The ore in sight stands practically from the 186-foot level to the surface, and is developed by east and west drifts.

Later, a three-compartment vertical shaft was located south of the inclined shaft and sunk to a depth of 118 feet. It cut the ore-body at 105 feet and had not passed through it at 118. The ore is hard, white quartz, heavily sulphuretted.

In the original exploratory work done by Capt. Thies, 8 tons of ore, including a large amount of hanging wall slates broken from the east drift of the inclined shaft, were milled and yielded 55 dwts. free gold and ½ ton of concentrates. Later, 143 tons of ore from the east drift of the same shaft were milled, realizing 500 dwts. free gold, and 7 tons of concentrates, assaying $602 per ton. The percentage of sulphurets (iron pyrites) in the ore varies from 5 to 7 per cent.

There are over 2 acres of old tailing dumps, 8 feet deep, which material assays from $7 to $8 per ton.

Towards the end of 1896, the mill was increased to 40 stamps with 10 Frue vanners, and a 5-foot Huntington mill, with 2 Triumph concentrators were added. The milling capacity is 1¼ tons per stamp per day, and 12 tons per day in the Huntington mill.

Besides the above equipment, 2 reverberatory roasting furnaces, 50 x 9 feet hearth, and a chlorination plant with two 2-ton barrels, filters, etc., were built.

MINES IN MERIWEATHER COUNTY.

The only mine of importance is the WILKES, situated in the extreme northwest corner of the county. It is stated to have produced $50,000 from 1873 to 1878, during which years the vein (composed of quartz lenses 8 to 10 inches thick) was mined to a depth of 130 feet. The ore, consisting of quartz, with about 3 feet of the adjoining wall-rock, mills about $4 per ton.

In the spring of 1895 the mine was opened and operations conducted on a limited scale by Mr. John Cross.

MINES IN TOWNE COUNTY.

A zone of ore-bearing schists about 3 miles in length extends across the State line into Clay county, N. C. (see p. 70).

The WARNE mine, in Clay county, N. C., is situated on Brasstown creek, about 8 miles southwest of Haysville and not more than ¼ mile north of the Georgia line.

The developments consist of a 60-foot shaft, at the bottom of which the quartz-vein is stated to be 2 feet in width. There are no underground workings of consequence. The property is equipped with a 10-stamp mill driven by a turbine wheel with a 20-foot water-fall.

The OLD FIELD mine, in Towne county, Ga., adjoins the Warne on the southwest. Considerable exploratory work has been done, and a number of quartz-veins located. There appears to be a good opportunity here for hydraulicking the saprolitic material over a considerable area; with a ditch line 2 miles in length a head of 160 feet can be attained.

The NANCY BROWN mine adjoins the Old Field on the southwest, beyond which lies the HUNT mine property, where the main developments consist of a shaft 45 feet deep, and a tunnel 60 feet long. In the former, the vein, which is composed of vitreous quartz, is stated to vary from 18 to 36 inches in width, and various assays have shown values ranging from $10 to $17. In the tunnel the quartz-vein, which strikes nearly east and west and stands vertically, has a thickness of from 12 to 15 inches, which has given reported mill-test values of $13. The country is mica-gneiss and -schist, striking N. 70° W. These rocks are filled with quartz-stringers or veinlets, and in general the district is not unlike that of the Dahlonega region in Lumpkin county.

The JACK BROWN property adjoins the Hunt on the southwest. The main prospect is an 8-foot quartz-vein, which has a promising appearance and is stated to carry values from $9 to $125 per ton. The strike of the vein is N. 75° E., and the dip is nearly vertical.

The WELBORN HILL mine is situated about ½ mile west of the Jack Brown on a parallel zone of auriferous schists. It was last worked several years ago by two shafts respectively 125 and 70 feet deep, cutting two parallel quartz-veins respectively 36 and 30 inches wide. The strike is N. 40° E. and the dip steeply to the northwest. The property is equipped with a 10-stamp mill of the Hall type.

THE CAROLINA BELT (IN GEORGIA).

In the eastern part of the State an auriferous district, which probably represents the southwesterly extension of the Carolina belt, is developed to some extent in McDuffie, Warren, Wilkes, Lincoln, and Columbia counties.

The most prominent mine in this district is the SMITH mine, operated by Mrs. J. Belknap Smith. It is situated 14 miles northwest of Thomson in McDuffie county.

A 3-foot vein of white quartz, carrying free gold, pyrite, chalcopyrite and galena, and milling from $8 to $24 by simple amalgamation, has been developed by two shafts to a depth of 160 feet, and for a distance of about 300 feet along the strike (nearly north and south). The mill (10 stamps) is located three miles from the mine on Little river. No attempt is made to save the sulphurets, and the tailings are stated to carry as high as $12 per ton.

Other mines in this district are the Columbia, Egypt, Tatham, Williams, Warren, and Magruder.

GOLD MINES IN ALABAMA.[1]

MINES IN CLEBURNE COUNTY.

All of the more important mines of the county are located in the Arbacoochee district, situated 7 miles southeast of Heflin, the nearest railroad point. In the earlier days extensive placer mining was carried on about ¾ of a mile southwest of the mining village, Arbacoochee, principally in the Clear Creek valley. The auriferous deposit at this point covers nearly 100 acres in Sections 5, 6 and 7, T. 17, R. 11 E.

During the summer of 1895 a pocket of very rich quartz was opened up in one of the old placer pits on the boundary line between Sections 6 and 7. It is stated that between $1000 and $2000 of coarse gold was taken from about 400 pounds of ore and the immediately overlying gravel. This find created considerable local stir, and prospecting was being pushed along the strike of the quartz-vein as far as the direction could be determined from the very limited dimensions of the ore lens, the latter having a maximum width of 8 inches, a dip of about 30°, and pinching rapidly along the strike in a distance of about 6 feet. The ultimate value of this find will depend on the continuation of this shoot in length and depth, or the discovery of new ore-bodies along the strike of the veins. Prospecting along this ore-lead was still in progress during 1896.

The only hydraulic work in the State was carried on for a short time by the Arbacoochee Hydraulic Company on side-hill deposits, about ½ mile east of Arbacoochee. The limited supply of water and poor management are given as the reasons for failure.

The Anna Howe, the Anna Howe Extension, the Crutchfield and the Valdor are adjoining properties in the Arbacoochee district. These

[1] For a more complete statement concerning gold mines and mining in Alabama see *Bulletins 3 and 5 of Alabama Geological Survey*, referred to on p. 13.

mines are located on a series of narrow, irregular, lenticular quartz-veins having quite a flat dip. The Anna Howe was developed to a depth of about 100 feet when the vein pinched out and the mine was abandoned. The equipment consists of a Huntington mill and Frue vanner.

The Chulafinnee district is about 8 miles west of Arbacoochee, in Sections 14, 15, 16, 22, 23, 24, 25, T. 17, R. 9 E. As at Arbacoochee, extensive placer mining has been prosecuted here in the past, but has long since been abandoned. Recent prospecting has disclosed some rich quartz-stringers on the property of Mr. Burrell Higginbotham. The old King mine, at which a stamp mill was in operation over 20 years ago, is in the same vicinity.

The Turkey Heaven District comprises a series of mines situated along the base of the Turkey Heaven mountains. Among the more important properties are the Miller, the Crown Point, the Moss-Back, the Pritchard, the Lucky Joe, the Hicks-Wise, the Lee, the Crumpton, the Middlebrook, the Sutherland, the Bennifield, the Marion-White, and the James Moore.

The Crown Point mine is equipped with a 5-stamp mill. The Moss-Back is one of the early discoveries; it is equipped with a 10-stamp mill. The LUCKY JOE[1] is the most extensively developed mine in the district. It was opened in 1893, and a stamp-mill (Fraser and Chalmers make) erected. It is stated that the mill runs saved $2.27 a ton by amalgamation, the cost of mining and milling being $1.35 to $1.45 per ton. The capacity of the mill, using 30-mesh screens, was 30 tons per day. The pay-ore lies in chimneys and shoots from 3 to 4 feet thick, dipping about 30° eastward. The workings consist of about 300 feet of drifting and cross-cutting. Apparently the development of ore did not prove satisfactory, as the mine was abandoned during the summer of 1894.

The MOSS-BACK mine, near the Lucky Joe, was opened in the early seventies. A 10-stamp mill was erected in 1890.

The Hicks-Wise mine was developed by a vertical shaft 110 feet deep with levels at 20, 40, and 85 feet. Of 3000 tons of ore milled it is stated that a yield of $2 per ton was obtained by amalgamation. The ores are graphitic.

The LEE mine is developed by an inclined shaft sunk to a depth of 40 feet on the dip of the ore-body (45°), on which level a drift of 121 feet in length has been run in ore, which varies from 2 to 5 feet in thickness. The plant in operation in 1894 consisted of 3 arrastras and a Blake crusher. It is stated that the ore will mill $5 per ton.

The MIDDLEBROOK is opened by an inclined shaft 20 feet deep on an ore-body 5 feet in thickness. Panning tests have shown $5 per ton.

[1] For full description of this property ee *Engineering and Mining Journal*, vol. lvi, 1893, p. 79. by W. M. Brewer.

The SUTHERLAND ore-body closely resembles the Middlebrook. It has been but slightly developed to a depth of about 30 feet. An old-fashioned wooden stamp mill with iron shoes stands on the property.

The Kemp Mountain district is situated in T. 17, R. 10 E. and T. 17, R. 11 E. The two most important properties are the Eckels and the Golden Eagle. The ECKELS mine was opened in 1893 by an open-cut 8 feet deep and 50 feet long, exposing ore, thin seams of quartz in decomposed graphitic schist, the entire distance. A shaft was sunk from the floor of the open cut to a depth of 65 feet. The dip is vertical down to 36 feet, when it changes to 60° south. A cross-cut at the bottom of the shaft showed that the ore-body had narrowed down to 18 feet. In 1894 the shaft was deepened to 100 feet and the same conditions found to hold. No sytematic work of treating the ore has been done.

The GOLDEN EAGLE (formerly known as the Price) mine has been opened by a shaft 75 feet deep on the dip of the ore-body about 50° southeast. The vein-matter, quartz-stringers in hydromica-schist, is 10 feet thick at the bottom of the shaft and is highly sulphuretted, containing also arsenical pyrites. Some rich ore has been found here.

The DYNE-CREEK Company has recently made a number of openings in the vicinity of Kemp Mountain and south of Arbacoochee.

MINES IN RANDOLPH COUNTY.

The only mine of prominence is the Pinetucky. It might be classed as belonging to the Arbacoochee district, and is located about 2 miles south of Micaville and 14 miles from Heflin, near the northern boundary of the county.

The occurrence of gold-bearing quartz here was discovered by a Mr. Knight in the early days of gold digging. Numerous shallow workings, perhaps the most extensive at any one point in the South, extend in a continuous line for over a mile along the outcrop of the vein, and give evidence of the large amount of work done here in time past, as well as of the continuity of the vein. These old workings have been carried to a maximum depth of 70 feet, and a large amount of drifting has been done on the course of the vein, which is nearly north and south, the dip being about 20° east. The vein is a fissure of hard, bluish quartz in walls of garnetiferous hornblende-schist. It varies in thickness from the fraction of an inch to 12 inches. The values are concentrated in chimneys or shoots, and vary from a trace to $150 a ton. It is claimed that the ore will carry an average of $40 per ton. About one-half of the gold is free-milling, the other half being contained in the sulphurets (pyrites). The percentage of pyrite in the

ore is less than 1 per cent. Assays of concentrates have shown from $90 to over $600 per ton.

A few years ago a complete and well-constructed 10-stamp mill of Western pattern (Fraser and Chalmers) was erected on the property about 700 feet east of the outcrop. A vertical shaft was started in the mill house with the object of cutting the vein in depth and hoisting the ore direct to the grizzly and crusher, situated at the top of the building. This shaft was sunk to a depth of 50 feet and then abandoned for lack of funds. In the spring of 1895 the property was leased to the Fair Mining and Milling Company of Chicago, which began operations by sinking three (3) vertical diamond drill-holes. The first of these was driven to a depth of 205 feet without cutting ore. The cores showed granite at a depth of 55 feet, which alternated with the garnetiferous country schists to the bottom of the hole. The second hole, bored about 150 feet east of the old workings to a depth of 130 feet, also failed to reach the vein. The country schists were passed through at 60 feet, below which they alternated with granite. The third hole, only 80 feet east of the old workings, was drilled to a depth of 70 feet. After passing through the country schists, granite was encountered at a depth of 47 feet, immediately below which the quartz-vein was found 12 inches in thickness; below that a layer of soft gouge, and below that garnet-schist and granite. A working shaft was started at this point.

In gold quartz-veins of this size the result obtained by diamond drill borings might often be misleading, as the gold-bearing vein can at times be distinguished from other quartz only by its gold contents; about this the drill-core, and still more the cuttings used as assay samples, can give no reliable information. However, such explorations may disclose other facts of interest, as, for instance, in this case the discovery of granite overlying the vein in depth, which may give a clue to the formation of the vein and more intelligently direct search for it.

The prospecting work at this mine was done with a small Sullivan drill ($\frac{7}{8}$-inch core). The drill runner furnished by the Sullivan Diamond Drill Company, of Chicago, received $90 per month. The cost of underground labor in this district is $1 per day and for top labor 80 cents to $1; cord wood, 75 cents per cord; freight to Heflin (by wagon), 14 miles, 20 cents per 100 pounds.

Near the center of this county, at Wedowee, some placers have been operated.

The Goldberg district lies in the extreme western part of the county, running partially into Clay county near Abner. Attention has been paid in this direction almost entirely to placer mining along the bottom of Crooked creek. A very considerable amount of prospecting has also been done on the vein formations, but no regularly producing mines

have yet been developed. Arsenical pyrite is of common occurrence in the district.

MINES IN CLAY COUNTY.

The more important mining operations have been carried on in the Idaho district, which embraces an area of about 3 miles square. The country-rocks are graphitic mica- and hornblende-schists, often garnetiferous. The principal properties are the Idaho, Hobbs, Laurel, Chincapina, California, and Horns Peak.

The IDAHO (or Franklin) mine is situated in Sec. 3, T. 20, R. 7 E., on the northwestern side of Shinbone ridge. The main ore-body consists of a large mass of the country schists interlaminated with quartz-seams and largely stained with manganese oxide. The schistosity stands almost vertical. This ore-body, which has a thickness of 50 feet, is opened by cuts which extend for over 300 feet along the line of strike and to a maximum depth of 60 feet.

The second ore-body is about 150 feet northwest of the above. It is locally called the "Little Sampson vein." But little work has been done here.

The Idaho ore is stated to carry $2 per ton in free gold. The milling plant, which was in operation in the winter of 1896, consists of a 5-stamp mill (crushing capacity 10 tons in 24 hours), and a 5-foot Huntington mill (crushing capacity 20 tons in 24 hours), the former crushing through round punched 2 mm. screens, and the latter through 1 mm. slotted screens. The pulp from both mills goes over shaking coppers and thence over stationary coppers, which are barred with riffles. From here it flows over blanket sluices 8 feet wide at the Huntington and 4 feet wide at the stamp-mill. The cost of mining and milling is stated to be 50 cents per ton, and the cost of delivering from mine to mill 15 cents per ton.

The following rates of wages are paid: Miners, 75 cents per day (10 hours); foremen, millmen, and engineers, $1 per day; millwright, $1.25 per day. The cost of fuel is $2 per day.

The Laurel mine is supposed to be an extension of the Little Sampson ore-body, and the character of the ores is very similar.

The CHINCAPINA mine is situated on a ridge to the north of the Laurel and Idaho mines. The character of the ore-body is similar to that of the Idaho, though the dip is more inclined, about 30° southeast. No work of consequence has been done.

At the California mine a 10-stamp mill was erected and operated several years ago.

The HORNS PEAK mine is situated about 1 mile west of the Idaho. The ore-body, which resembles the others in this district, has been

opened by a cross-cut tunnel, determining its thickness to be about 30 feet. Tests made in a small 5-stamp mill located in the vicinity have demonstrated a saving of $2 per ton by amalgamation.

MINES IN TALLADEGA COUNTY.

The occurrence of gold in this county is limited to the extreme eastern portion, in the Blue Ridge mountain range. The Riddle and Story mines have been worked to some extent.

The ore-body at the RIDDLE mine is a highly sulphuretted quartz-vein, having a very flat dip towards the southeast. It has been opened by an inclined shaft on the dip to a depth of 100 feet. The thickness of the quartz lenses is about 4 inches, pinching to a mere seam in places. Assays have shown values varying from $20 to $150 per ton. The prospect pits extend for over half a mile on the course of the vein.

The STORY mine lies in the adjoining section to the Riddle. The ore was mined some years ago from an incline on the vein to a depth of 60 feet. It is similar to that of the Riddle mine.

The occurrence of gold in Coosa, Chilton, Chambers and Tallapoosa counties has been fully described by Dr. W. B. Phillips in Bulletin No. 3, *Geological Survey of Alabama.*

The latter county was at one time the seat of extensive mining operations in the Goldville, Hog Mountain,[1] Silver Hill, Gregory Hill, Blue Hill, and Farrow Mountain districts.[2]

GOLD MINES IN TENNESSEE.

The gold produced in this State has been obtained entirely from petty placer workings in Monroe, Polk, McMinn, and Blount counties. The most prolific sources have been the deposits along Coco creek, a tributary of the Hiawassee river in Monroe county. Other gold-bearing streams in this county are the Citico and Cane creeks, and the head-waters of the Tellico river. Along Whippoorwill branch, a tributary of the Tellico, small gold quartz-veins have been discovered, but they have never been worked.

In the latter part of 1896 a company known as the Cooper Gold Mining Company was organized for the purpose of developing the Coco creek gold fields.[3]

[1] Extensive prospecting work has recently been done at Hog Mountain with the result of showing the existence there of a number of thick veins of low grade ore, averaging perhaps $4 or $5 a ton.

So also in the vicinity of the old Ulrich mines, and across the river at the Bonner, Terrell, and Gunn mines, much work has been done within the past twelve months.

[2] See Bulls. Nos. 3 and 5, *Geolog. Survey of Alabama.*

[3] *Eng. and Min. Jour.*, vol. lxii, p. 374.

CHAPTER V

THE MINING AND MILLING PRACTICE AT SOME OF THE CHARACTERISTIC PLACER AND FREE-MILLING MINES.

THE CRAWFORD (OR INGRAM) MINE, STANLY COUNTY, N. C.

This mine is situated 4 miles southeast of Albemarle, in the Carolina belt. It represents a type of working in virgin placer ground, the gold being coarse, usually in nuggets. The mining tract (180 acres) comprises a flat hollow or depression, averaging 250 feet in width, which is drained by a small branch. The country-rock is the dark greenish Monroe slate (sedimentary), lying in a flat synclinal trough. The auriferous grit, lying on the slate floor, is composed of angular fragments of quartz and country-rock bound in a clay matrix; the cement is often hard and stained a brownish or black color. The quartz is of a milky, vitreous variety, seldom showing ferruginous stains; some pieces show parallel walls (vein structure) from a few inches up to 1 foot in thickness. No free gold has been found in this quartz. The thickness of the grit in the center of the synclinal basin is from 1½ to 2 feet, and of the over-lay 2 to 4 feet, thinning out towards the edges. The length of the deposit on the company's property is about a quarter of a mile. The adjoining property on the north is owned by Mr. F. A. Fesperman, whose place has been worked by tributors. The gold found at the Crawford is altogether coarse, from the size of a pin's head to nuggets of considerable weight. The largest nugget was found on August 22, 1895, and weighed 10 pounds. The so-called De Berry nugget, found April 8, 1895, weighed 8 pounds 5 ounces. These nuggets are scarcely at all water-worn, being rough and irregular in shape. The fineness of the gold varies from 850 to 900.

On the hillside to the west of the placer mine several quartz-veins have been explored by shallow openings along the outcrop. One of these is from 2 to 3 feet thick, and dips steeply to the east, cutting the slates both in strike and dip. The quartz, so far as explored, has been found generally barren, though in several places gold has been panned from the crushed rock; but no larger pieces have been found giving any possible clue as to the origin of the nuggets of the placer deposits.

Gold was first discovered in this bottom in August, 1892, the prop-

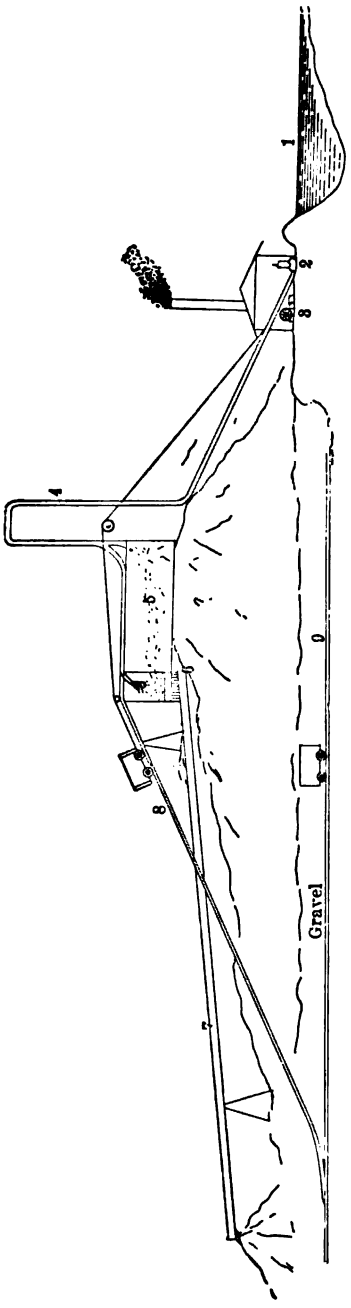

Fig. 6.—Sketch of method of working gravel at Crawford mine, Stanly county, N. C. (Not drawn to scale.) 1, reservoir; 2, pump; 3, hoisting engine; 4, stand-pipe; 5, washing-box; 6, grizzly; 7, sluices; 8, inclined plane; 9, track on bedrock.

erty being at that time a portion of the W. S. Ingram farm. For two years it was worked spasmodically by tributors, and 16 to 17 pounds of nuggets were obtained. In 1894 the property was bought by the Crawford Mining Company of New York, and was put under the able management of Mr. Richard Eames, Jr., of Salisbury, N. C. A sketch of the method of working which was being pursued in 1895 is given in fig. 6.

The bottom having insufficient grade to carry off the tailings with the limited amount of water at hand, a washing tank and sluice were put up on the side hill at an elevation of about 30 feet above the creek. The deposit was mined by a system of parallel trenches 12 feet wide, worked from the lower end of the deposit upward. Track was laid in these as they advanced. The upper 6 to 18 inches of the over-lay were thrown off, the remaining 1½ to 2 feet, together with the true grit (gravel) and 6 to 12 inches of the bed-rock, were shovelled into cars holding about half a cubic yard. These were trammed to the foot of the inclined plane (8), and hoisted to the top of the washing plant by a small friction-drum engine (3) (see fig. 6). This tank was built of plank and is about 50 feet long, 18 feet wide and 6 feet high. On one of the sides there is a door or opening 4 feet wide, reaching to within 4 inches of the bottom to a sill. The grit was dumped into the tank and a constant stream of water kept flowing over it. The action of this stream was reinforced by water played on the material from a hose nozzle under a head of 30 feet. This head was obtained from a stand-pipe (4) to which water was pumped from a reservoir (1) by means of a Hall duplex pump (2) with a 4-inch discharge. Excepting at the time of the clean-up, the tank was kept nearly full of gravel, and under the combined action of the two streams of water, closely imitating natural agencies, a very good concentration of the coarser nuggets was attained in the tank. The material, partly assisted with a rake, flowed over a grizzly (6), the bars of which were set 1½ inches apart. The coarser pebbles and boulders were forked off, while the finer gravel and sand were carried down into a sluice (7) situated below the grizzly. The sluice was 400 feet long, 12 inches wide and 10 inches deep, and had an inclination of 6 inches in 10 feet. It contained only about 20 feet of riffles, and these were situated about 100 feet below the grizzly. Originally, the whole sluice was filled with riffles, but these were removed when it was recognized that they were superfluous for saving gold. The first hundred feet of the sluice were found to aid in thoroughly washing and disintegrating the material before it reached the riffles, and gold was seldom found below the first four or five feet of the riffles. The upper riffles consisted of diagonal slots cut in 2-inch plank, which was laid in the bottom of the sluice. The lower riffles were of the longitudinal variety (see fig. 8).

The upper riffles, as well as the surface of the material in the tank, were examined every evening for larger nuggets. A complete clean-up was made at odd intervals, depending upon the richness of the material worked on, etc. The gravel in the tank was entirely worked down by means of the hose, the coarser nuggets picked out by hand, and the heavy sand, together with similar material found in the bottom of the sluice, after taking up the riffles, was washed in a rocker. No quicksilver was used, there being no fine gold whatever. A loss of gold would more likely be in the form of larger nuggets, which might be overlooked in forking out the coarser material, or which, on account of their round form and size, might roll over the riffles to the tailing heap. One large nugget, of the shape and size of a hen's egg, was found on the latter. Clay balls (sluice-robbers) also cause considerable loss.

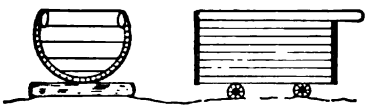

Fig. 7.—Rocker used by tributors; Crawford Mine.

Upper End. Lower End.

Fig. 8.—Riffles in sluice-box; Crawford Mine. Scale, ¼ inch=1 foot.

When working to full capacity, 25 men were employed at these mines—5 men at the tank and sluice, 1 playing the hose and dumping cars, 1 raking gravel out of the tank, and 3 helping the material down the sluice and over the riffles, forking out the coarser pebbles. The latter force was necessitated by the limited supply of water and the desire to work as large quantities as possible. Their work might perhaps have been assisted by the use of a much shorter sluice, and a somewhat steeper inclination of the same, without endangering loss in gold of such a coarse character. The remainder of the force, excepting foreman and engineer, were employed in digging gravel, taking up bed-rock, etc. An average day's output consisted of 80 carloads, about 45 cubic yards of loose gravel. Two and one-half to three cords of wood were burnt a day, at 65 cents per cord. Labor was paid at the rate of 60 to 65 cents per day. These figures, with reasonable additions for superintendence, supplies, etc., placed the cost of mining gravel by this method at about 50 cents per loose cubic yard. From June until November, when the water-supply is very limited, the right of mining the gravel was let out to tributors, who turned in as royalty ¼ of the finer gold, including

pieces up to 1 ounce in weight, and ½ of the larger nuggets (above 1 ounce). The tributors worked in pairs, one pitting and taking out the bed-rock while the other one manipulated the rocker (cradle), shown in fig. 7. It is made up like a barrel, with half-inch staves, smoothed on the inside, with solid heads, the latter being a little more than half a circle. One wheelbarrow-load is put in the rocker at a time. After the gravel is thoroughly disintegrated by vigorous motion of the rocker, the pebbles, etc., are thrown out, and finally, by a light movement, the finer and heavier portions are examined closely by eye. It is practically a panning process on a larger scale. Fifteen minutes are occupied in cleaning up one charge.

THE MILLS PROPERTY, BURKE COUNTY, N. C.

This property is situated near Brindletown, about 14 miles southwest from Morganton. It comprises an area of 2460 acres, including the eastern portion of Pilot Knob and the western flanks of the South mountains, being drained by the waters of Silver creek. The problem here presented is the reworking of old gravel deposits by a simple hydraulicking process where the grade is sufficient, or, where this is not the case, by raising the material to the surface by hydraulic elevators.

Geologically, the locality is in the South mountain belt. The general strike of the crystalline schists is N. 20° W. and the dip 20° N.E. The rocks are decomposed to a considerable depth, reaching often 50 feet and at times 100 feet. The strike of the auriferous quartz-veins is N. 60° to 70° E. and the dip 70° to 80° N.W. These veins are usually from a knife edge to several inches in thickness, and are too small to work individually. One vein from 12 to 18 inches in thickness has been explored, but was found to be almost barren. The gravel deposits occupy the present stream beds and adjoining bottoms, and the ancient channels now covered with deep over-burden and extending into the hillsides which flank the mountain. From Pilot Knob and along its lower slopes, a number of these deep channels radiate in all directions.

The facilities for obtaining water for mining purposes are good, though beset with difficulties. The numerous streams which have their rise in the South mountains are small though of good flow throughout most seasons, and it is practicable to collect their water and lead it to the larger part of the mining ground in ditch and flume-lines and reservoirs with sufficient head for sluicing and hydraulicking purposes. However, the summer months cannot be depended upon for steady work, as the water-supply is apt to be cut short by droughts. The chief impediment is in the loss of grade before the mining ground in the lower country is reached, owing to the deep and numerous indentations of the mountains which it is necessary to circumvent. It is impossible to

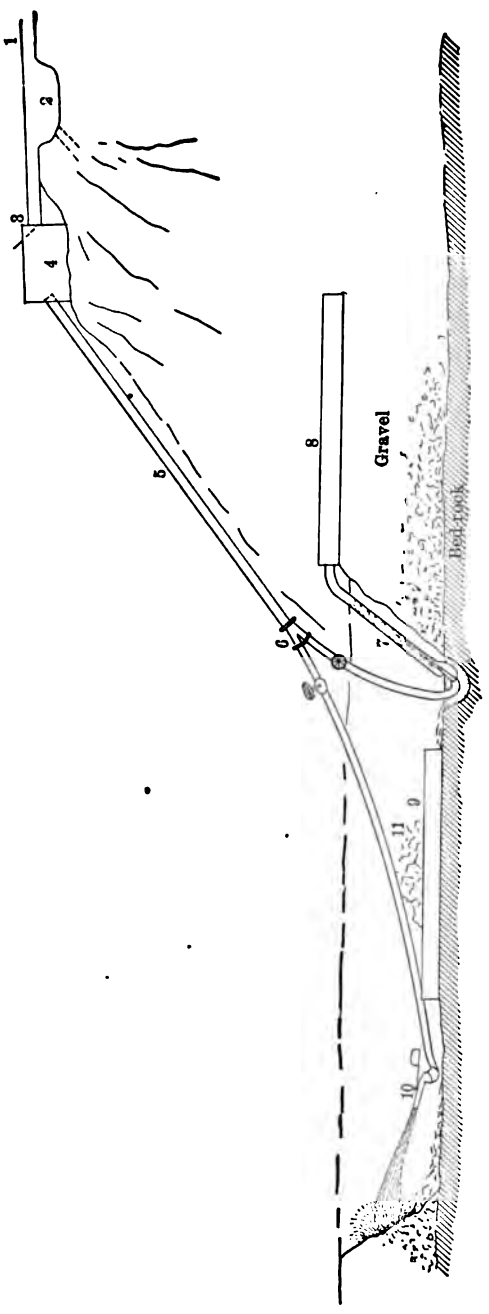

Fig. 9.—Sketch of proposed Hydraulic work on Mills Property, Burke County, N. C. (Not drawn to scale.) 1, ditch; 2, sand pit with drain; 3, screen at head of penstock; 4, penstock; 5, pipe (10 and 8-inch); 6, Y branching into two 7-inch pipes; 7, hydraulic elevator; 8, top sluice-boxes; 9, pit sluice-boxes; 10, giant; 11, bowlder and pebble heaps.

water some portions of the sidehills except by pumping into reservoirs or by constructing expensive syphon-lines.

Brindle creek on the Mills property was the site of the first discovery of gold in this part of North Carolina, in 1828. With few exceptions, most of the virgin placer ground above alluded to has, by more or less continuous mining operations since then, been worked as high as water could be obtained with the present ditch lines. Much of the gravel has been washed over as many as three times. As no regular records have ever been kept, it is impossible to speak intelligently of the value of these gravel deposits. Small channels yielding as high as $20 per cubic yard have been worked, but in general the gravel will yield from 4 to 50 cents. At present, the available mining ground may be divided into two general classes: first, the bottom and ancient channel gravel deposits; second, the decomposed country-rock in place, containing belts of small auriferous quartz-veins. Not much attention has been paid to the latter, excepting by tributors who in a spasmodic way have worked some deposits on the flanks of Brindle ridge, gouging out the small rich quartz-veins, and extracting the gold by crushing in hand-mortars and panning; they pay a royalty of 16⅔ per cent. to the owner. Captain J. C. Mills at one time successfully worked one of these small quartz-belts by sluicing to a small stamp-mill (Dahlonega method), but the mill was destroyed by fire and never rebuilt.

In 1894 an English company was formed with the object of again reworking the principal gravel deposits and obtaining as a by-product the monazite, which occurs concentrated with the gold and is derived from the adjacent country-rocks by disintegration. Over a year was spent in preparing the mining ground, building and repairing ditches, flumes, etc. It was proposed to concentrate the work at two points, the first in the bottom land of Silver creek, using a giant and hydraulic elevator; the second in the bed of Magazine or Parker branch, using a giant and continuous sluice-box system.

PLACER DEPOSITS ON SILVER CREEK.

Silver creek forms one of the main drainages of the South mountains. The placer deposits which it was proposed to rework on the Mills property are situated near its headwaters. They are about 1 mile in length and are located mainly upon the west bank, on which the gravel often extends out a distance of 500 to 600 yards. The main difficulty encountered was the want of fall in the bed, a feature common to many Southern placers. It amounts in this case to less than 1 foot in 100. To overcome this obstacle for hydraulicking with continuous sluice, the use of the hydraulic gravel elevator was decided upon. Fig. 9 gives a

rough sketch of the plant and method proposed. Twelve miles of ditch and flume line (1) carry the water from a reservoir, through the Dan Sisk gap in the South mountains, to a penstock (4), situated 200 feet above the level of the creek bed. The ditch is cut about 8 inches deep by 20 inches wide, at a cost of about 25 cents per rod, and is given a grade of from 1½ to 3 inches in 100 feet. The flumes are, at ordinary grade, 18 inches wide by 12 inches deep (see fig. 10).

A sill, bent, top and side brace are erected every 6 feet at the jointing point and middle of each box. The bents are made of rough lagging seldom more than 6 inches in diameter, the greatest height of trestle being less than 30 feet. The sill of the flume acts as a cap for the posts. Wherever a small grade becomes necessary, the width of the flume is doubled. The cost of erecting these flumes is small, equal to about the cost of the material in them. Lumber is worth $6 to $7 per thousand.

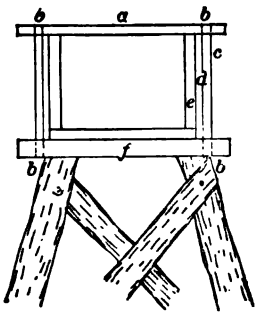

Fig. 10.—Flume, Mills Property, N. C. Scale, ⅛ inch=1 foot. *a*, 1x3-inch board; *b*, 1-inch holes; *c*, 1x3-inch board; *d*, wedging; *e*, 1½-inch plank (sides and bottom); *f*, 2x4-inch sills and cap for bent.

The water, before reaching the penstock, flows through a sand pit (2, fig. 9), to catch sand, etc., washed into the ditch line from the side. It then enters the penstock after passing through a screen (3) for removing leaves, sticks, etc. The pipe (5) leading from penstock is 10-inch spiral riveted sheet-steel (with No. 16 Birmingham gauge), coated with coal-tar and connected with flanges. Smaller curves are made by placing cast-iron bevelled wings between the gaskets of the flanges, larger ones by suitable elbows. Near the gravel pit the 10-inch pipe branches out through a Y (6) into two 7-inch pipes, supplied each with a gate-valve, one leading to the giant pen and the other to the hydraulic elevator (7). These are both of California type and manufacture.[1] An illustration of the latter in detail is given in fig. 11. The principle of this device is too well-known to require a description. It

[1] Joshua Hendey Machine Works, San Francisco, Cal.

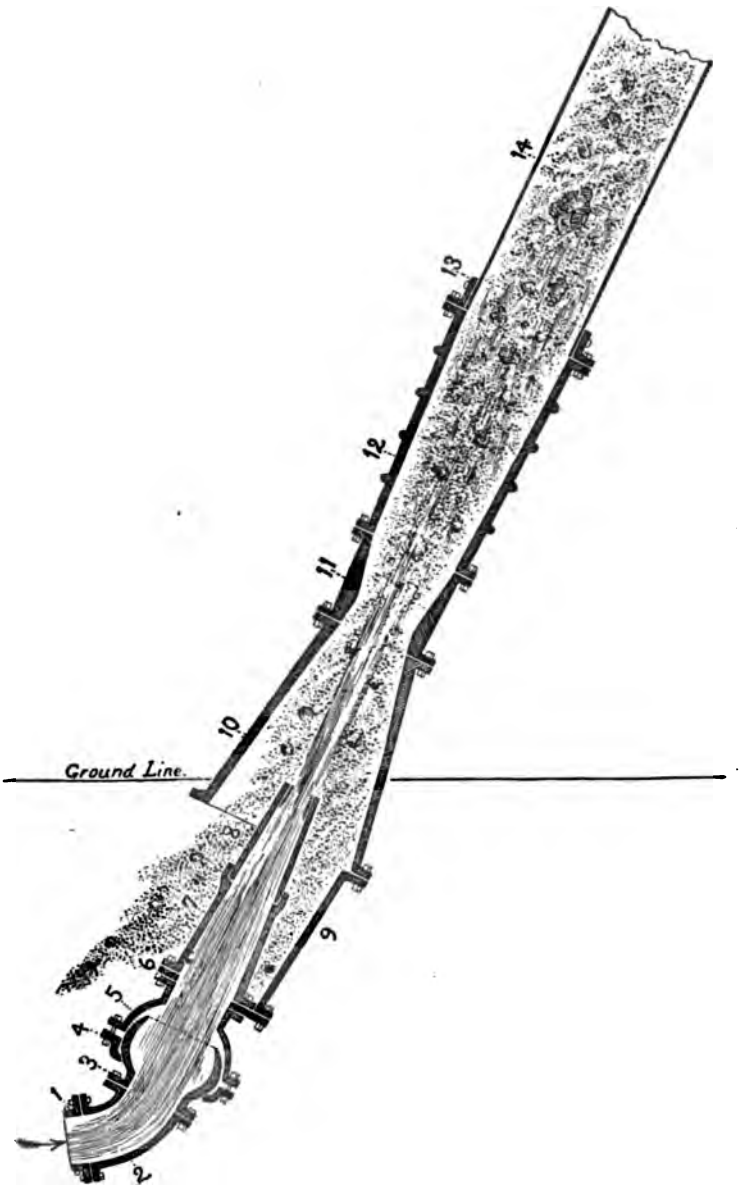

Fig. 11.—Hydraulic Gravel Elevator, J. C. Mills' land, Burke Co., N. C.

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is intended to keep the elevator stationary as long as possible, as its installation consumes considerable time. A pit must be sunk in the bed-rock, and as the elevator must also drain the workings (a drain on the top of bed-rock to the initial point of working was considered too expensive), the water would gain too much headway while the elevator is moved. The work in the main pit will be carried diagonally up the banks of the stream, so as to gain as much grade as possible. As soon as there is room, a sluice-box (9) will be placed between the working bank and the elevator-pit. A cross-section of this is given in fig. 12.

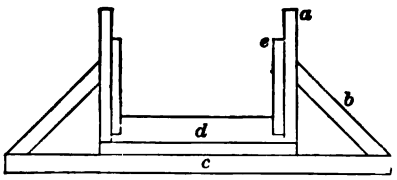

Fig. 12.—Section of Sluice-box, J. C. Mills land, Burke Co., N. C. Scale, ½ inch=1 foot. *a*, 1½-inch surfaced pine plank (sides and bottom); *b*, 2x4-inch brace; *c*, 2x4-inch sill; *d*, 1x4-inch riffle; *e*, 1x8-inch sand-board.

The upper part of this sluice will be filled with 3-inch by 4-inch blocks and the remainder with 1-inch by 3-inch cross-riffles, placed 11 inches apart and held down by a sand-board, which is halved down on them. Both will help to protect the sluice-box against wear. All pebbles, etc., more than ½ inch in diameter will be forked out of the sluices and left in the pit (11). After being raised by the elevator, the material will pass through another sluice (8), the tailings from which will be worked for monazite. It is expected that by far the largest part of the gold will be saved in the first sluice.

Active work was commenced in July, 1895, and after three months' washing with the giant and hydraulic elevator the undertaking was abandoned. So far as the working of the machinery was concerned, the operations were entirely successful, but the yield in gold and monazite did not meet the expectations.

The ¾-acre of ground (chiefly tailing dumps, which had already been worked over in an irregular and imperfect manner several times) that was worked to an average depth of 9 feet, yielded $350 in gold, and the monazite was so full of magnetite, rutile, etc., that its saving was not warranted.

It is by no means intended by this to condemn the property, for it is of course unjust to judge its value from this single test; and while it is undoubtedly true that the resources are insufficient to support a company organized on so large a capitalization as this English company was, there is no reason why smaller operations should not be entirely successful.

PLACER DEPOSITS ON PARKER BRANCH.

The Magazine or Parker branch is a tributary of South Muddy creek. Its source is at the foot of Pilot Knob, and from the latter several gravel channels run towards it, sometimes entirely covered with soil, so as to make their location unrecognizable at the surface. One of these, the Magazine channel, has been extensively worked, first by open hydraulic work, and afterwards at the upper end, where the over-burden grew too heavy, by a tunnel, subsequently connected with the shaft. The former had a total length of 600 feet, and the latter a depth of 50 feet. The creek bed has also been worked, mainly with rockers. It was proposed to work this bottom, besides any side-hill channels that might be found, by giant, sufficient fall being available to carry off the tailings in a continuous sluice-box below. Water for this work was brought a distance of 5 miles to a large reservoir on the divide between South Muddy and Silver creeks, and from here in 2 miles of ditch and flume, along the foot of Pilot Knob, to a reservoir situated 100 feet above the creek bottom. This reservoir was designed to hold the water contained in the ditch after the gate at the large reservoir had been closed in the evening; and this was to be the first water to be used in the morning before that from the large reservoir had time to reach this point. The placer deposit in the creek bed has a total width of 400 feet. The old gravel banks, etc., were to be broken down and the material run into sluices similar to those described above, the tailings being carried down the branch to South Muddy creek.

These operations were, however, never undertaken, owing to the liquidation of the company before that point was reached.

THE CHESTATEE COMPANY, LUMPKIN COUNTY, GA.

The work pursued here, and its ultimate object, present special features of interest, and might warrant a greater application in the Southern gold-fields. The plant and property of this company are situated 2½ miles from Dahlonega, on the Chestatee river, about ½ mile above the entrance of Yahoola creek. The property comprises about 250 acres of placer ground on the banks of the river, together with about 1 mile of the stream bed. The main object in view was to turn the river into a new channel and to work the stream-gravel, as well as that in the adjacent bottoms.

At the lower end of the property a dam was thrown across the river and a substantial and well-constructed power station erected, supplying the power, by means of two 66-inch Leffel wheels, for a Blake duplex 12-inch by 24-inch pump and a 50 horse-power dynamo. The Leffel wheels were originally installed to furnish motor-power to a centrifugal

sand-pump for raising gravel from the channel excavation, but this was later on abandoned in favor of a hydraulic gravel elevator. The substitution was made for economic reasons as well as for the fact that the latter had in its favor greater simplicity, more constant work, and easier portability, as well as greater facility of installation.

This elevator is the design of Mr. W. R. Crandall, the general manager of the Chestatee Company. It combines cheapness and compactness of construction, and a novel feature is the introduction of air at the nozzle whenever the inlet of the suction-pipe is entirely submerged. Its mechanism and operation have been admirably described and illustrated in a paper by Mr. Crandall, presented at the Pittsburgh meeting of the American Institute of Mining Engineers in February, 1896. We believe that this form of elevator may have quite an extended and useful application in many parts of the Southern field, and in order to intelligently bring it before those of our readers to whom the Transactions of the American Institute of Mining Engineers may be inaccessible, we cannot do better than to repeat the descriptive portions of Mr. Crandall's paper,[1] changing the numbers of the figures to suit this report:

"Fig. 13 shows the elevator in detail; Fig. 14, the manner in which it is set; Fig. 15 the details of the flume, etc. In all the figures the parts are lettered respectively as follows:

A. Cast-iron elbow at the base of the elevator.
B. Wings or vanes, to straighten the water before it enters the nozzle.
C. Nozzle.
D. Air-cap.
E. Air-inlet pipe, to furnish air when the bottom of the discharge-pipe is submerged.
F. Studs to support the discharge-pipe and to keep it and the nozzle in line.
G. Cast-iron flanged throat.
H. Discharge-pipe.
I. Discharge-box.
K. Hood for discharge-box.
L. Adjustable wood-packing around discharge-pipe.
M. Discharge-flume.
N. Adjustable flume-supports.

This elevator, as used at the Chestatee mine, near Dahlonega, Ga., where it has been gradually developed and perfected under the needs of practice, consists essentially of an elbow, A, longer at one side than the other, and coupling by means of a flange to a 5-inch pipe. At the other extremity are a flange, into which the nozzle screws, and three studs, F, which support the throat into which the gravel and water enter to be elevated. The throat slips inside the 6-in. lap-welded pipe, H, for discharging into the flume on the bank, from which it may be conveyed wherever desired.

The whole apparatus, except the discharge-pipe, may be readily carried by two men. If it be necessary to move the elevator often, to keep up with the drainage, the portable character of the outfit is a great advantage.

At the Chestatee mine the practice is about as follows: The water-supply is conducted to the mine through a 9-inch pipe. At a suitable point the water is divided, and a 5-inch pipe conveys that used by the lift, while a 7-inch pipe conducts to the giant. Valves are provided at the Tee, so that one or both

[1] *Trans. Am. Inst. Engs.*, xxvi, 1897, pp. 62-68.

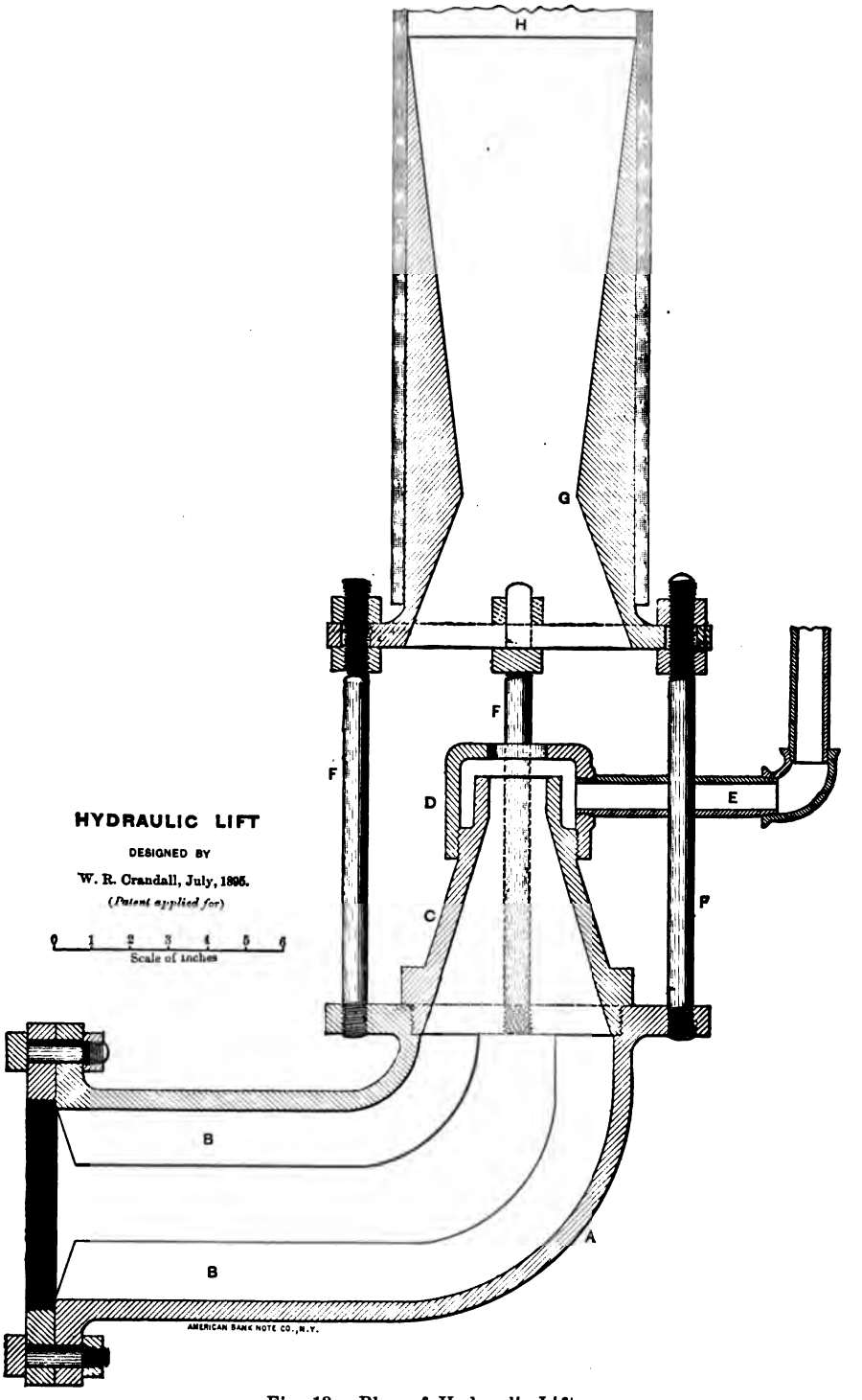

Fig. 13.—Plan of Hydraulic Lift.

may be shut off as necessity requires. The lift is set into the slate to such depth as may be desired, and connection is made with the water-supply pipe. The discharge-pipe is then slipped over the throat and the discharge-flume is put in place, the discharge-pipe being set at such an angle of inclination as may be necessary to give proper grade to the tailings-flume and allow the pipe to extend a few inches through the bottom of the hooded box.

The air-pipe, E, is then screwed into place, and the lift is ready for operation. We govern the depth to which we set the lift into the bed-rock slate by the hardness or softness of the latter. If it be hard, frequent moving is cheaper than cutting slate-drains. If soft, we go as deep as the slate will stand without timbering. This we find to be about 7 feet.

A main drain is then started in the general direction of our work, from which laterals are afterwards cut as required; and, at some suitable place near the lift-pit, a box about 6 feet long by 32 inches wide is set into the drain at grade, and in this is placed a cast-iron "grizzly" having round holes 2½ inches in diameter. This catches any rocks which may escape the forkers, and insures that nothing will get to the lift which will not readily pass through the throat, which has, when new, an opening of three inches.

We use straight-bar riffles in the discharge-flume to catch any gold that may pass through the lift. This we find in practice to be about 5 per cent. of the total amount recovered, a result largely due to the fact that, when work is started at a new pit, the ground-sluices are not long enough to settle the gold thoroughly.

Whenever the drainage afforded by a pit is exhausted the pipe-line is extended, a new pit is sunk near the gravel-breast, and the work is continued as before.

As the work follows the general course of the river, the tailings are discharged into the river at the nearest point, the portable tailing-flume being extended far enough to insure the safety of the immediate bank. The tailings finally flow through a ditch into the river.

We usually use about 200 feet of 5-inch pipe in the lift water-supply before extending the 9-inch pipe-line; and we often move up 100 feet, dig the pit, re-set the lift and get ready for work again in one 12-hour shift with 5 men.

As to the work which the lift will accomplish, I may say that we are using a lift with 1½-inch nozzle, discharging through a 3-inch throat into a 6-inch pipe, and lifting an average of 18 feet vertically, with water at about 60 pounds pressure per square inch.

As we are quite near the river, and have the drainage of a side-hill, the surface-water is considerable, probably fifty gallons per minute. We use a 1¼-inch nozzle on the giant, and the lift readily handles all this and all the dirt and gravel we are able to wash to it. The latter we estimate, from measurements taken at different times, to be about ½ cubic yard per minute of 'topping.' The quantity of gravel is hard to determine, owing to varying conditions; but it is safe to say that it is all that the amount of water employed will wash."

Water is supplied to both the elevator and the giant by direct pressure (about 60 pounds to the square inch) from the Blake pump. This direct appliance of pressure, without intermediate stand-pipe or reservoir, has proved very successful, the only precaution necessary being to shut off the pump before closing the feed of the giant or elevator. It

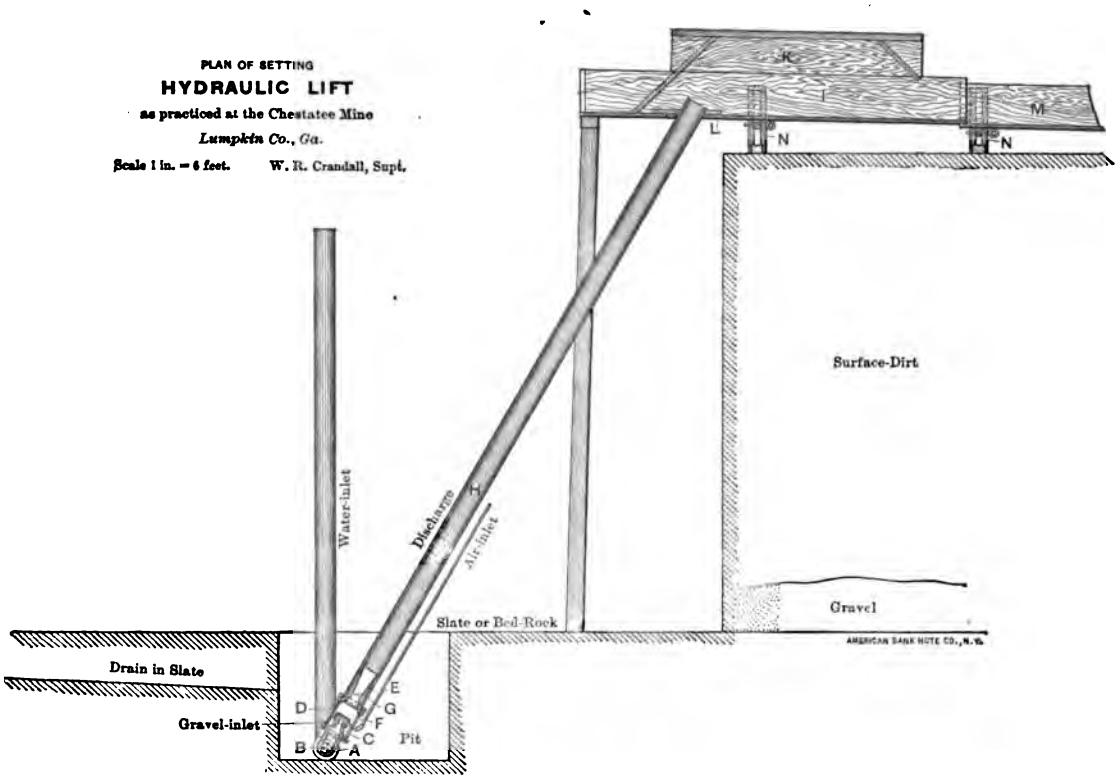

Fig. 14.—Plan of setting Hydraulic Lift.

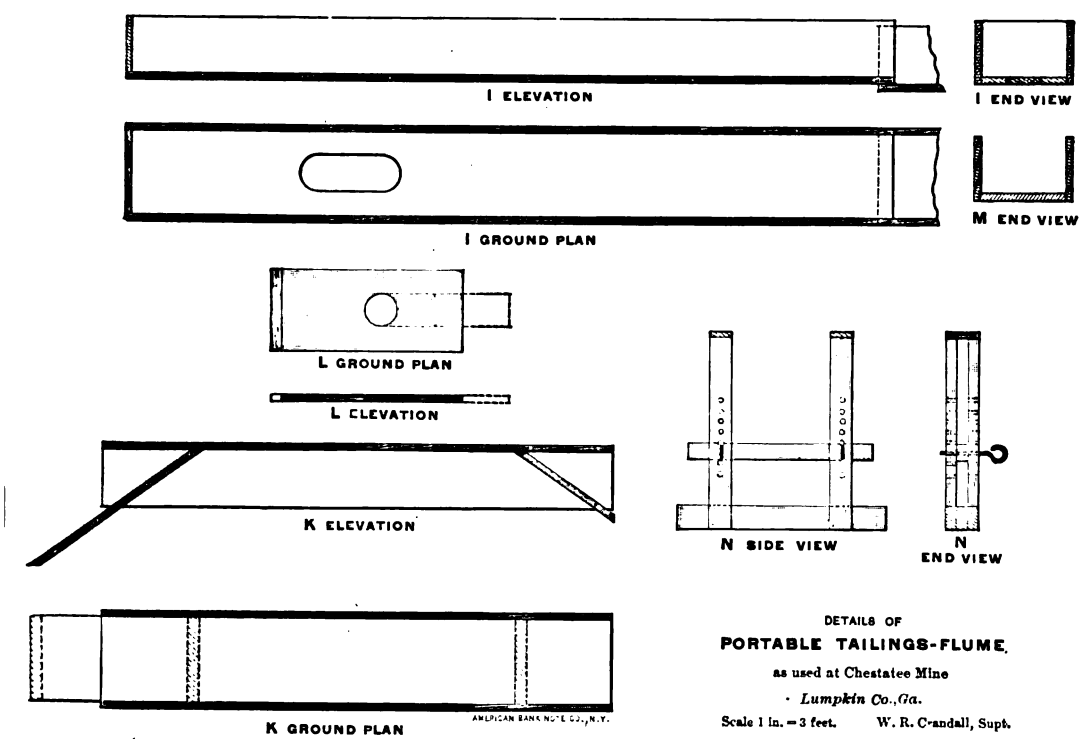

Fig. 15.—Portable Tailings-Flume.

has also this advantage, that when occasion demands it, smaller nozzles can be used and the pressure thus increased.

The channel is cut 30 to 35 feet wide, down to bed-rock in depth, and has a total length of about half a mile. It runs almost parallel to the river, and from 50 to 200 yards from the north bank of the same. When completed, the waters of the river will be turned into it by means of a wing-dam.

The gravel above the bed-rock in this channel is auriferous and has paid the expenses of the preliminary excavations. It averages 1 foot in thickness, with 6 to 10 feet of over-lay. The latter was worked off during the night shift (using electric light illumination), and the gravel thus exposed, as well as about 2 inches of bed-rock, taken up during the succeeding day.

CHESTATEE RIVER DREDGE-BOATS, LUMPKIN COUNTY, GA.

Dredge-boats of various descriptions have been at work on the Chestatee river for a number of years. The work has been spasmodic, and failures are more often recorded than successes. The river, where operated on, is about 100 feet in width and of variable depth. Numerous shoals make dredging difficult.

A steam vacuum dredge [1] was operated for a time on this river; it did good work, especially in cleaning up the bed-rock. The main difficulty, and the reason for abandonment, was the banking up of the tailings around the boat, finally hemming it in.

The Roy Stone method,[2] using the principle of the hydraulic elevator, was attempted as early as 1883, but proved unsuccessful. In the summer of 1895 there were two dredge-boats on the river, one above and the other below New Bridge. The former of these, operated by Mr. Frye, is on the principle of a continuous bucket elevator. So far it has not been operated successfully, the buckets and continuous link-chain proving entirely too light for the work. The other boat was operated at a small profit by Mr. Jacquish. It was erected seven years ago by the Bucyrus Steam Shovel Company at an initial cost of about $15,000. After being worked for two years it lay idle until the summer of 1895.

The machinery is installed on a scow, 26 by 70 feet, drawing 3½ feet of water. It consists of a Bucyrus shovel (scoop) of 1¼ tons capacity, derrick and hoisting-drums for operating the same, a small horizontal engine and a centrifugal-pump for supplying fresh water to wash the gravel, and a 60 horse-power locomotive boiler. A barge, 100 by 20 feet, lying alongside of the dredge-boat, carries the sluices. There are

[1] See *Gold*, by A. G. Locke, 1882, p. 890.
[2] See R. W. Raymond, in *Trans. Am. Inst. Min. Eng.*, vol. viii, p. 254.

two lines of sluice-boxes, each 3 feet wide and 18 inches high, running the full length of the barge, and filled with longitudinal riffles, made up in five-foot racks, composed of 1 by 3-inch slats set 1 inch apart. The gravel is discharged from the shovel on an iron-shod platform at the head of these boxes, where the boulders and larger pebbles are removed. The gold is caught almost entirely in the upper two racks; the tailings run off into the river in the back of the boat. When in favorable ground, the dredge will scoop and deliver an average of 1 bucket every 2 minutes. When examined there were 3 men on the dredge-boat, engineer, fireman and craneman, and 6 men at the sluice-boxes. Work is carried forward up stream, the scow being moved against the current by anchoring the scoop and pulling the scow towards it by means of the crane engine. The main wear and tear are on the lip of the scoop, and on the chains. A steel lip 12 inches in length wears out in about six months. The river ground is leased on a royalty of from 5 to 10 per cent. by the property owners. It is said that gravel as low as 5 cents per cubic yard can be worked at a profit.

In the spring of 1896 a boat, equipped with a Marion Steam Shovel Company's dredging outfit, was in operation under the management of Messrs. Benham and Helmer. A pontoon alongside of the dredge carried a line of sluice-boxes. The material from the dredge was dumped on a grizzly at the head of the sluice line and washed down by a stream of water from a No. 8 Held and Cisco centrifugal pump having a capacity of 4500 gallons per minute. The sluice-boxes were 70 feet in length, 64 inches wide and 12 inches deep, and provided with riffles. There was a device for carrying back the tailings and depositing them in the excavation behind the machine. The efficiency of the dredge was stated to be 800 to 1200 cubic yards per 10 hours. The expenses were estimated at about $18 per day, and the gross returns at $40 to $120 per day.

THE DAHLONEGA METHOD, WITH SPECIAL DESCRIPTION OF THE HEDWIG MINE.

The Dahlonega method of mining and milling is one which is particularly adapted to the large bodies of low-grade auriferous saprolitic schists, such as exist in the Dahlonega district of Georgia. It consists in cutting down the soft, decomposed ore-bodies by means of a hydraulic giant, the water from which carries the material through a line of sluices to the mill situated some distance below the workings, usually on the banks of a stream from which it derives its water-power. In the mill the coarser and heavier portions are retained by means of a screen, and are fed to the battery by hand, the mud and fine silt being carried through into the river. Generally, a third of the gold saved is caught

in the riffles of the mine-sluices, the remainder being obtained in the mill.

HISTORICAL NOTES.

The Dahlonega method first originated in 1868 by sluicing the material from the mines to platforms near the mill, from where it was hauled to the mill in carts. This was improved by placing bins, with perforated bottoms, in the stamp-mills, from 4 to 5 feet above and back of the mortars; underneath this bin was a settling-box, in which the sandy material settled and the slimes overflowed. At the Child's mill, near Nacoochee, a plant was erected, consisting of a series of washing and sizing plate-screens, in which three sizes, coarse, medium and sand, were made and milled separately. It is stated that all the millable ore was saved in this way, in a clean shape, free from mud.

The present practice is to flush the material on to the mill floor back of the batteries, this space in the mill-house being practically arranged as a large bin with a slat screen (distance between slats about ½ inch) at one end. Frequently a V-shaped storage-tank is situated outside of the mill, where the material is collected and flushed into the mill as occasion requires.

THE WATER-SUPPLY.

The system of reservoirs, ditches, etc., in this district is by far the most extensive and best equipped in the Southern gold-belt. The principal water-line is known as the Hand and Barlow ditch, having a total length of 34 miles, the main canal being 20 miles long, 6 feet wide and 3 feet deep, and furnishing 800 miners' inches. The grade averages 5 feet to the mile, being 4½ feet on straight lengths, with slightly steeper grades on bends. The cost of digging this canal was about $1 per rod; the total cost, including trestling, etc. (excluding syphon-line), was $1000 per mile. The canal crosses the Yahoola valley about 1 mile northeast of Dahlonega, in a wrought-iron syphon-tube (see Plate VIII) 2000 feet in length. The difference in level of the two ends is about 6 feet, and the pressure at the lowest point is 90 pounds per square inch. The inside diameter is 3 feet, the thickness of the pipe being $\frac{3}{16}$ inch in the upper and ⅜ inch in the lower part. It was built in 1869.

Four miles from Dahlonega the water is carried across a similar depression in a wooden tube which is ⅞ of a mile in length and 3 feet in outside diameter. It is made of 3 by 5-inch staves, trimmed so as to make a tight fit. These staves are laid in wrought-iron hoops, forming alternate joints; the last stave is driven in with a maul. This tube was built in 1868, and is still in good condition.

Auxiliary ditches run off from the main canal to the various mines. A portion of this water was formerly leased out at the rate of 12 cents per miner's inch for 24 hours. The present owners, The Hand &

WROUGHT-IRON SIPHON PIPE (3 FEET INSIDE DIAMETER), 2000 FEET LONG, ON THE HAND BARLOW DITCH LINE, CROSSING THE YAHOOLAH RIVER, ONE MILE FROM DAHLONEGA, GA.

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DAHLONEGA METHOD OF MINING, SHOWING GIANT AND GROUND SLUICE.

Barlow United Gold Mines and Hydraulic Works of Georgia, have, however, been lately using the whole amount in working their own mines. Besides this system there are several smaller ones, bringing the total length of ditch-lines up to about 80 miles.

A unique feature of the water-supply at the Findley mine is the elevation of the water from the ditch-line to a reservoir situated 152 feet above it, by means of a hydraulic pumping engine made by the Filer & Stowell Company, of Milwaukee, Mich. This pump is situated near the stamp-mill, 285 feet below the ditch-line. The water is led to it from the above ditch in a 16-inch straight-riveted feed-pipe 456 feet in length, and is discharged by it into a reservoir of 88,000 cubic feet capacity, a total vertical height of 437 feet, through a 12-inch steel pipe 1141 feet in length. The principle involved is that of the hydraulic ram, inasmuch as a large quantity of water under a lower head raises a certain portion of itself to a higher head, the remainder being waste. The machine, however, is of entirely different and, so far as known, novel construction. It is of the duplex pattern, the two engines being connected by gearing and with an 8-foot fly-wheel. Each engine has 3 cylinders in tandem, to which the water under the feed-head (123 pounds) is admitted and discharged by valves of the Riedler type. In one of these cylinders the water is raised to the greater head (190 pounds) at the expense of the feed-water, under head, going to waste in the other two. A snifting-valve is attached to the latter to give relief to the valves. The stroke is 18 inches, and at a high piston-speed of 250 feet per minute the pump works very smoothly. Tests had not been made, and no figures of efficiency could be obtained at the time of our visit. Such figures, as well as a more detailed description than could be made after a hasty examination, would be of great interest. The present working capacity of the pump is 600 gallons per minute.

MINING METHODS.

The general character of the ore-bodies has already been described (pp. 22 and 23). The depth of the saprolites (decomposed schists) in the Dahlonega region reaches often to 50 and sometimes 100 feet. Enormous openings have been made in these by the hydraulic giant, whole sides of the mountain being torn off in places (see Plate IX). The head employed in hydraulicking varies from 50 to 150 feet, dependent on the height from which water can be obtained. Where harder rock is torn loose, it is broken by hand-sledges and thrown into the ground-sluices. Powder is sometimes resorted to for breaking down the more resistant ledges. In order to shorten the distance in sluicing to the mill, tunnels are often run through the intervening hills (as at the Hand and Findley mines). The wooden sluice-line is supplied with longitudinal riffles throughout its entire extent.

In the pursuance of this method a large proportion of the material carried to the mill is perfectly barren, for the reason that the entire mass is not gold-bearing, but only certain streaks of it, which cannot be mined separately by this method.

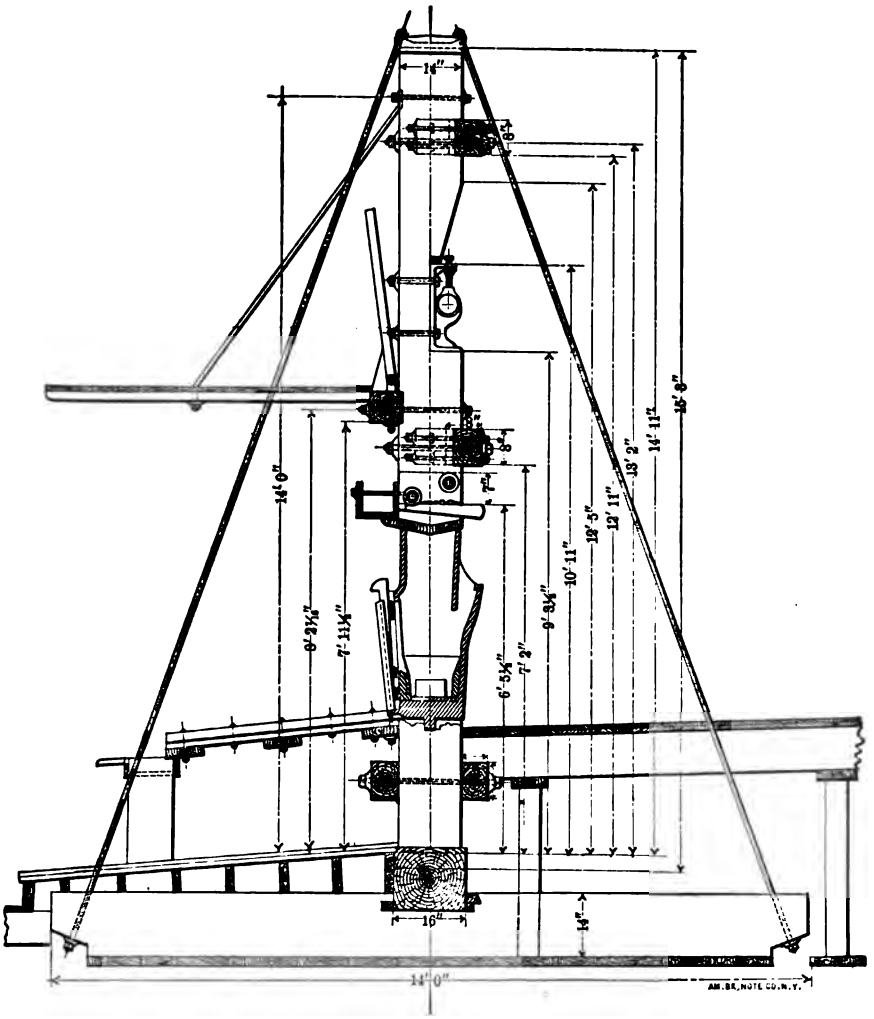

Fig. 16.—Vertical Cross-section of the 450-pound Hall Stamp-mill.

MILLING METHODS.

The Dahlonega method of mining and the milling material resulting from the same have developed a milling practice particularly characteristic of this district. The material floated to the mill is of necessity of small size, the larger pieces of rock being sledged before entering the flume. Thus crushing is dispensed with. Automatic feeders at the

mill have been tried, but were found impracticable, the variable hardness of the ore (only a small proportion being hard quartz and rock) making hand-feeding imperative.

The battery which is almost universally in use is that of the Hall type, invented and patented by Mr. Frank W. Hall, of Dahlonega. The usual weight of the stamp is 450 pounds. Figs. 16 and 17 give the two vertical sections of this mill. It represents novel features both in the battery and in the setting. The long battery blocks and a bed-rock foundation have been entirely dispensed with. The mill can be set upon any level piece of ground, a 2-inch plank platform forming practically the only foundation. The plan of construction (well shown in the drawing) makes the frame self-contained, the blow of the stamp and the reaction being absorbed and neutralized in the setting. Elasticity is maintained by the guy-rods. A suspended platform gives access to the props, cams, etc. The mortar is held in place by a rib on the bottom fitted in a corresponding gain in the mortar block. It is held down on the latter by wedges driven against blocks bolted on the inside of the battery posts. The small inside dimensions of the mortar are still more narrowed down by chilled-iron liners, which reach to within an inch of the dies. The main purpose of these liners is to bring the ore, on being fed, immediately under the shoes. They also protect the mortar against wear, and help to some extent in collecting and secreting amalgam. Quicksilver is fed to the batteries, and in some cases a considerable amount of amalgam collected is obtained from the mortars. The liners are fitted with dovetails and lugs at the end, and are finally held in place by two large keys driven against the screen frame, which is shod with wear iron on each side. On removing the front liner the mortar is opened to the floor. The dies, which sit in ½-inch depressions, are easily withdrawn, the back and side liners drop out, and the mortar can be cleaned in a few minutes. The whole clean up in a 10-stamp mill is accomplished in the space of half an hour. The front liner determines the height of discharge, which, when the dies are new, is about 2 inches. An annealed copper plate, 4 feet long and of the full width of the mortar, is in most cases considered sufficient for the outside amalgamation. The weight of the 450-pound stamp-mill is divided as follows:

	Pounds.
Stem or spindle	175
Head of boss	150
Tappet with keys	50
Shoe	75
Total weight of stamp	450
Die	50
Mortar	2100
Liners for same	240

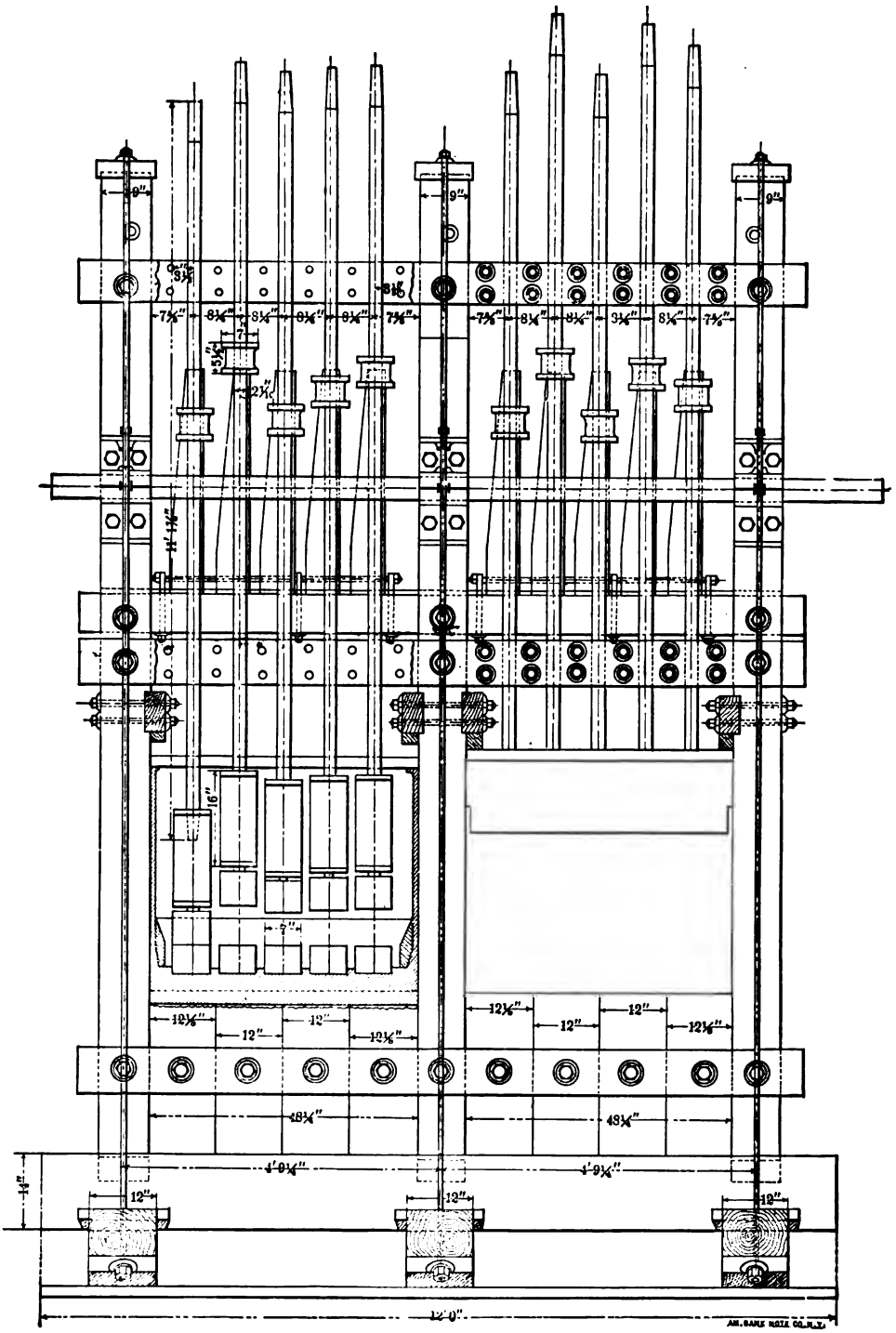

Fig. 17—Vertical Longitudinal Section of the 450-pound Hall Stamp-mill.

The average drop of stamp is 9 inches; number of drops per minute, 90. The whole machine is well constructed, and admirably fulfills its purpose of handling large quantities of the Dahlonega mill-stuff. The mill is also built with heavier stamps, and some slight changes are made in the frames of these. None of these heavier mills were seen in operation; but the setting employed is said to give as great satisfaction as in the lighter ones. Whether the application of this mill would be extensive for harder ores we are unable to judge. It certainly gives the extreme of rapid crushing, and might be adopted where such an object is in view.

The cost of these mills is light and that of installation small as compared with those of Western type.[1]

Almost all the mills in Dahlonega are operated by water-power, using turbines of the Leffel type for large quantities and low heads, and wheels of the Pelton type when the water is small in quantity under a high head. The crushing capacity of these mills varies from 2 to 5 tons per stamp of 450 pounds in 24 hours, depending greatly on the nature of the material run through.

In hydraulicking, and subsequent transportation by water, a partial concentration takes place, resulting in the eventual deposition of a largely enriched product in the mill. The light stuff and most of the slimes pass through the mill, in almost all cases without subsequent treatment, and the heavy product remains, the enriching being all the way from 2 to 5 times the original value of the ore in place. Besides this, free gold (generally about one-third of the total amount saved) is caught in the sluices before reaching the mill. Some of the losses in this process are evident from the above. Another serious loss, which is rapidly making itself felt as the mines grow deeper and less decomposed ores occur, is that of gold in the sulphurets. In such ores that carry sulphurets at all it is stated that they will run from 2 to 10 per cent., the concentrates from which are reported to assay as high as $40 and higher. Thus far, concentration has not been carried out on a working

[1] The following figures were obtained in the camp as representing the average cost of a 450-pound 10-stamp mill of the Hall type, as erected and used in the Dahlonega district:

All iron-work for batteries and setting, including copper-plates (f. o. b. works, Cincinnati)	$700 00
Freight on same, and cost of erection, about	500 00
Buildings, floors and sluices	400 00
Engine and boiler, with connections	600 00
Freight on same, about	150 00
Total cost of complete mill	$2350 00

Water-wheel and installation of same would cost about the same as engine and boiler. Chrome steel (made in Brooklyn, N. Y.) and Wilson pressed steel (made in St. Louis, Mo.) shoes and dies find about equal favor in the district, costing respectively 6 and 7 cents, f. o. b. works. Cast-chilled iron shoes are also used to some extent, at a cost of about 3 cents per pound.

Mills similar to the Hall type are also made in Gainesville and Atlanta, Ga.

basis. Despite many inquiries amongst local mill-men and others, we could hear no reports of losses in amalgamation resulting from so-called rusty gold. A loss of this nature was in a few cases ascribed to the finely-divided or flaky condition of the gold.

It is difficult to give any average values of the Dahlonega ores, or in fact to clearly designate exactly what the term ore applies to in this district. Material worth as low as 40 cents per ton has been milled at a profit. If this figure per ton, plus the gold saved in the sluices (20 cents per ton milled) represents the milling-value of 5 tons of material mined, as is stated to be frequently the case, then the value of the latter per ton must have been 12 cents. As a rule, however, the mill-stuff is of better grade than the above. The actual ore (quartz) is stated to assay from $1 up to exceptionally high values in the cases of rich stringers or pockets.

The cost of mining and milling throughout the district will average from 18 to 25 cents per ton of ore milled.

A description, somewhat more in detail, has been prepared of the following mine as representing perhaps most perfectly the Dahlonega method in its original type (of working soft saprolites or highly decomposed material).

DAHLONEGA METHOD AT HEDWIG MINE.

The Hedwig mine is situated near Auraria six miles west of Dahlonega. It consists of a large open cut about sixty feet in depth, run on a line of siliceous, micaceous ore-bearing schists, sixty feet in total width. The strike of the schistosity is N.E. and the dip 60° S.E. Three separate ledges of barren hornblende-gneiss (brick-bat) enclose two ore-bodies, striking and dipping conformably to them. But very few small quartz-stringers occur in the mass. Water is furnished to the giant (3-inch nozzle) under a maximum head of 60 feet from a reservoir situated on the hillside above the mine. Six men are employed at the mine at 80 cents per day (day-shift only).

The material is run to the mill in a flume 2800 feet in length and 14 by 16 inches in cross-section, made of oak boards. It is supplied with longitudinal riffles made of 2 by 3-inch post oak scantling. The grade of this sluice is 4⅞ inches in 12 feet at the lower, and 3½ inches at the upper end, that is, in the cut where it is not necessary to avoid overflows. The outside mill-bin holds about 240 tons, and the material is flushed from here to the inside bin, which holds 200 tons. Formerly there were three outside bins and the ore was hauled to the mill in cars.

The mill is a 40-stamp one of the Hall pattern, with a 12-foot driving pulley. It is driven by a 4-inch Ridgeway wheel, using 40 inches of water from two 1-inch nozzles. The water is supplied from the same

reservoir that furnishes the giant at the mine, by an 18-inch spiral riveted pipe-line, 2880 feet in length, under a head of 226 feet. The weight of the stamps is 450 pounds; drop 9 inches, 80 times per minute; discharge 2 inches; round punched screen, 120 holes to the square inch; length of plates (plain copper) 8 feet in two sections; ten of the stamps were fitted with silvered plates in 2-foot sections. Only the upper 4 feet of the plates in the mill are kept in shape; it is stated that no gold was saved on the lower ones. The tailings flow off through mercury traps. The overflow from both the outside and inside bins runs through a short line of riffled sluice boxes. At the time of our examination seven men were employed in the mill in two shifts, at 90 cents per day.

THE LOCKHART MINE, LUMPKIN COUNTY, GA.

The Lockhart mine is situated on the west bank of the Yahoola river near Dahlonega, Ga. It represents the working of ore-bodies of the Dahlonega type by underground mining.

The Dahlonega method of mining the saprolites was formerly employed here, and the old open cuts, now practically abandoned, are of considerable extent. This is the only mine in the Dahlonega district where underground work of any importance has been carried on. The ore-bodies consist of veins of the Dahlonega type (see description, pp. 22 and 23) where the quartz-filling has been more extensive, in places occupying the greater part of the fractured gneiss bands, which in a mining sense may be termed the vein, the boundaries of the gneiss bands forming continuous, smooth walls, and being the limit of the mineable ore. The normal strike of the schists at the Lockhart is northeast and the dip southeast; at one point, however, the schists bend around a mass of "brickbat," the strike being abruptly changed to the northwest and the dip to the northeast.

The principal work has been done on the Blackmore vein, where the country is a biotite hornblende-gneiss. The strike of this vein is N.E. and the dip 30°–60° S.E. It varies in thickness from 3 to 6 feet. The ore-body is opened by two adit-levels on the vein, 60 feet apart. The lower one, which enters the hillside at a depth of about 135 feet below the original outcrop, has a length of 400 feet, and the ore has been stoped out between it and the upper level for a distance of 100 feet from the face, which is the length of the ore-shoot so far as explored. This shoot has also been worked from the upper level to the surface. The pitch is steeply to the N.E. The ores from this shoot mill from $4 to $5 per ton. Besides this richer shoot the bottom level exposes ore throughout its entire length. This, however, decreases in quality as the mouth of the tunnel is approached, where it yields only $1. The system of work is underhand stoping, stulls being placed 6 feet apart to hold

up the ground. The ore is carried from the stopes in barrows to a platform at the mouth of the tunnel, from where it is hauled to the mill by carts.

The same vein has also been opened by a shaft, 50 feet deep, at the mill house, which is situated about 300 feet N.E. from the mouth of the mine. A drift 300 feet long was run on the vein here, which is reported to be 14 feet thick, carrying highly sulphuretted ores, which milled $4. This part of the mine is now under water.

Other ore-bodies have been opened up to some extent, but not sufficiently to say much of their nature.

The ore is treated in a 20-stamp mill of the 450-pound Hall type, erected originally for working material from open cuts by the Dahlonega method. No crusher or mechanical feeder is used, and no concentration of the sulphurets has so far been attempted, although they are stated to be of high grade. The ore is fed by hand, one man attending to each ten stamps. The drop is 6 to 8 inches, 60 times per minute, and the discharge is about 2 inches high. The screen used is a No. 9 Russia slot. The plates are 6 feet in length, plain copper.

For the hard ores, such as are at present mined, this mill can scarcely be considered of the best type, being too light. A crusher and automatic feeder would also be applicable here, as well as concentrators and a subsequent treatment of the sulphurets. The mill-power is furnished by a turbine wheel, obtaining its head of water from a dam across the Yahoola river.

The cost of production at the Lockhart is given as follows:

	Per ton of ore.
Mining	$ .90
Hauling	.15
Milling	.20
Other expenses	.10
Total cost of producing bullion	$1.35

The average milling value of the ore for the month ending February 3, 1895, is given as $4.15 per ton. No figures of the assay-values of the tailings could be obtained.

CHAPTER VI.

MINING, MILLING, AND METALLURGICAL TREATMENT OF SULPHURET ORES AT CHARACTERISTIC MINES.

THE REIMER MINE, ROWAN COUNTY, N. C.

This mine is situated about 6 miles southeast of Salisbury on the waters of the Yadkin river. Geologically it is in the Carolina belt. It represents a highly sulphuretted quartz-vein of marked persistency, with smooth walls and a clay gouge, the ore from which is worked by stamp-mill amalgamation, concentration of the sulphurets, and chlorination by the Thies process.

The vein is said to average 3½ feet in thickness, varying from 1½ to as high as 9 feet. The strike of the outcrop, which has been traced for 2 miles, is in an east and west direction. The dip is practically vertical. The sulphurets, mostly pyrite with a little chalcopyrite, occur in bunches, averaging about 10 per cent. of the ore. The quartz is compact, white and glassy. The wall-rock is a coarse crystalline eruptive, probably a quartz-diorite, and a fine-grained phase of the same.

Until 1884, when it was destroyed by fire, a concentration plant was in operation here. The concentrates which were obtained without previous amalgamation, were treated at the Yadkin Chlorination works near Salisbury. Work was not taken up again until 1894 and lasted until the fall of 1895. Fig. 18 gives a vertical section of the mine along the strike of the vein. The last work was concentrated at the bottom of No. 1 shaft (1), at a depth of 190 feet. The shaft is poorly constructed and very wet. A Cornish pump, driven by a belt from the crank of a small friction-clutch hoisting engine, raised the water from the bottom into a crude ring at the 150-foot level, from where a No. 9 Cameron sinking pump raised it to the surface. No development work was carried ahead, the ore being taken out by overhead stoping as soon as found. It was stated by the management that the poor condition of the mine and the crude method pursued was due to the more or less experimental nature of the late underground developments. The size and substantial construction of the mill and chlorination plant seem, however, to have gone beyond this stage. On account of the limited development the mine was worked in three shifts of eight hours each, with two miners and helpers on each shift, paid respectively $1.50 and

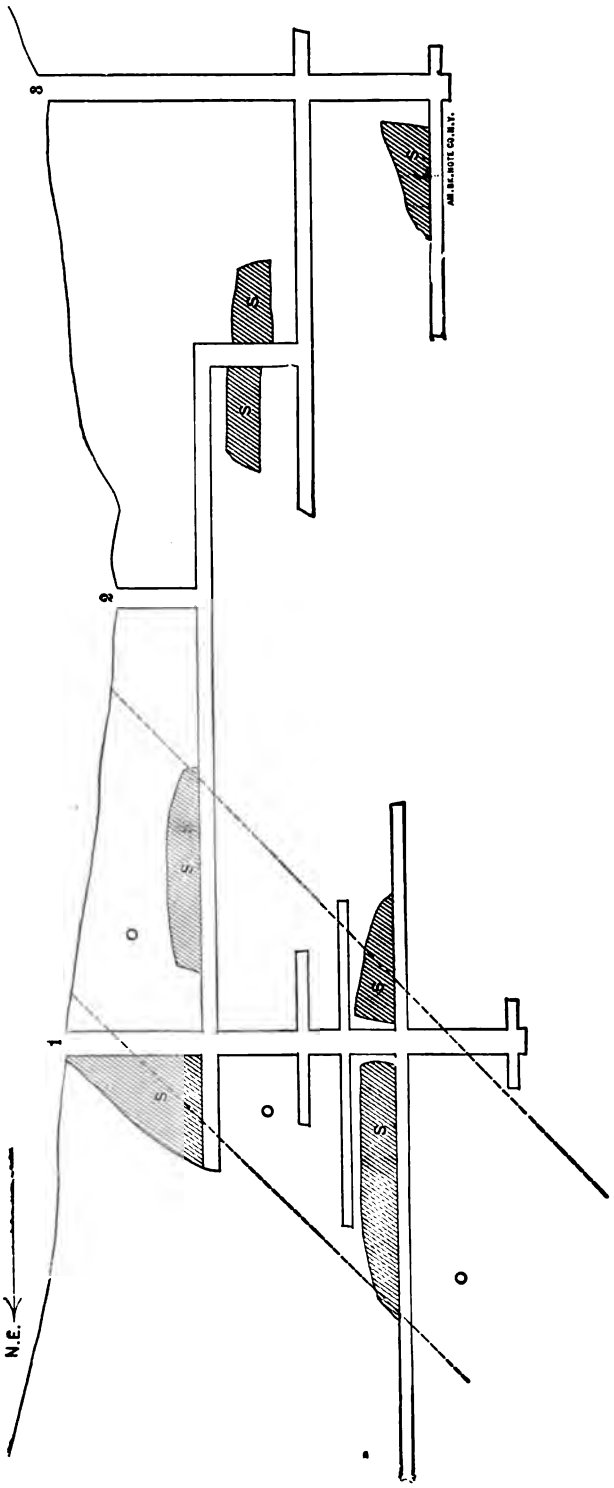

Fig. 18.—Vertical Section on the Strike of the Vein, Reimer Mine, N. C. Scale, 1 inch=80 feet. 1, shaft No. 1; 2, air-shaft; 3, shaft No. 2; O, dip of ore-shoots; S, stoped ground.

$1. The engineer, fireman and top-labor worked in two shifts of twelve hours each. No definite information could be gained regarding the cost of mining; but under the conditions existing, it must have been excessive. The mill is a 20-stamp one, built by the Mecklenburg Iron Works.[1] The mortar (fig. 19) is of a modified California type, and of medium width and depth. A novel feature in this mortar is a large opening above and in back of the screen by which the inside of the screen can be reached to clear it of foreign clogging matter. The inside plates may also be taken out through it without disturbing the screen. The weight of each stamp is 750 pounds, given 5- to 7-inch drop, 90 drops per minute. No inside plates are used at this mill. The height of the discharge is 5 inches, when the dies are new. The screens are 40-mesh, brass wire. The outside plates are similar to those at the Haile mine (see p. 136) The amount of ore milled was about 1 ton per stamp in 12 hours. About ⅓ of the gold extracted was saved by amalgamation. The tailings from the plates were concentrated on 2 Frue and 2 Triumph vanners, producing about 1 ton of concentrates in 12 hours, running from $30 to $40 per ton.

The concentrates were roasted in a large reverberatory furnace located in the mill building, the area of the hearth being 9x41½ feet. The capacity of this furnace was stated to be 4 roasted tons in 24 hours at a cost of $1.25 per ton. The furnace was worked in two 12-hour shifts with two men on each shift, head roaster at $1 and helper at 85 cents. Two cords of wood, at $1.25 per cord, were burnt in 24 hours.

The chlorination was carried on in a 1-barrel plant with a capacity of 4 roasted tons of concentrates per 24 hours. The building is arranged for the addition of another barrel which would allow the same work to be done in 12 hours, giving better opportunity for precipitation, and reducing the total cost of chlorination. The charge and the method of working was identical with that pursued at the Haile mine (see p. 140).

[1] The Mecklenburg Iron Works of Charlotte, N. C., Captain John Wilkes, Manager, make a specialty of gold-mining and milling machinery. In the summer of 1895 this company erected a 5-stamp test mill at their works, connected with a complete chlorination test plant having a capacity of half a ton of raw concentrates per day. As being of interest and value in a paper of this kind, we have obtained from them the following list of the cost of milling and chlorination plants erected in the South. The figures given are outside ones and apply in each case to a complete automatic plant.

The cost of the machinery for a 10-750-pound stamp mill with grizzly, crusher, self feeders, silvered inside and outside plates, Triumph concentrators (4 to every 10 stamps), engine and boiler, together with all attachments, and plans for erecting and locating machinery, is given at $5700 f. o. b., Charlotte, N. C. The same for a 20-stamp mill is $10,350.

The complete cost of a 10-stamp mill as above, set up (in the vicinity), will be about $8000. Of a 20-stamp mill, about $14,000.

The approximate cost of a 1-barrel chlorination plant with two reverberatory furnaces, erected, is given at $5500. The same for a 2-barrel plant with four furnaces at $9700.

The complete cost of a 10-stamp mill with concentrators, roasting furnaces and a Thies chlorination plant with all necessary power and expenses may be figured at $1200 per stamp. For a 20-stamp mill at $1000 per stamp, and for a 40-stamp mill at $900 per stamp.

The price of shoes and dies of a chilled charcoal iron mixture is 3 cents a pound f. o. b. works.

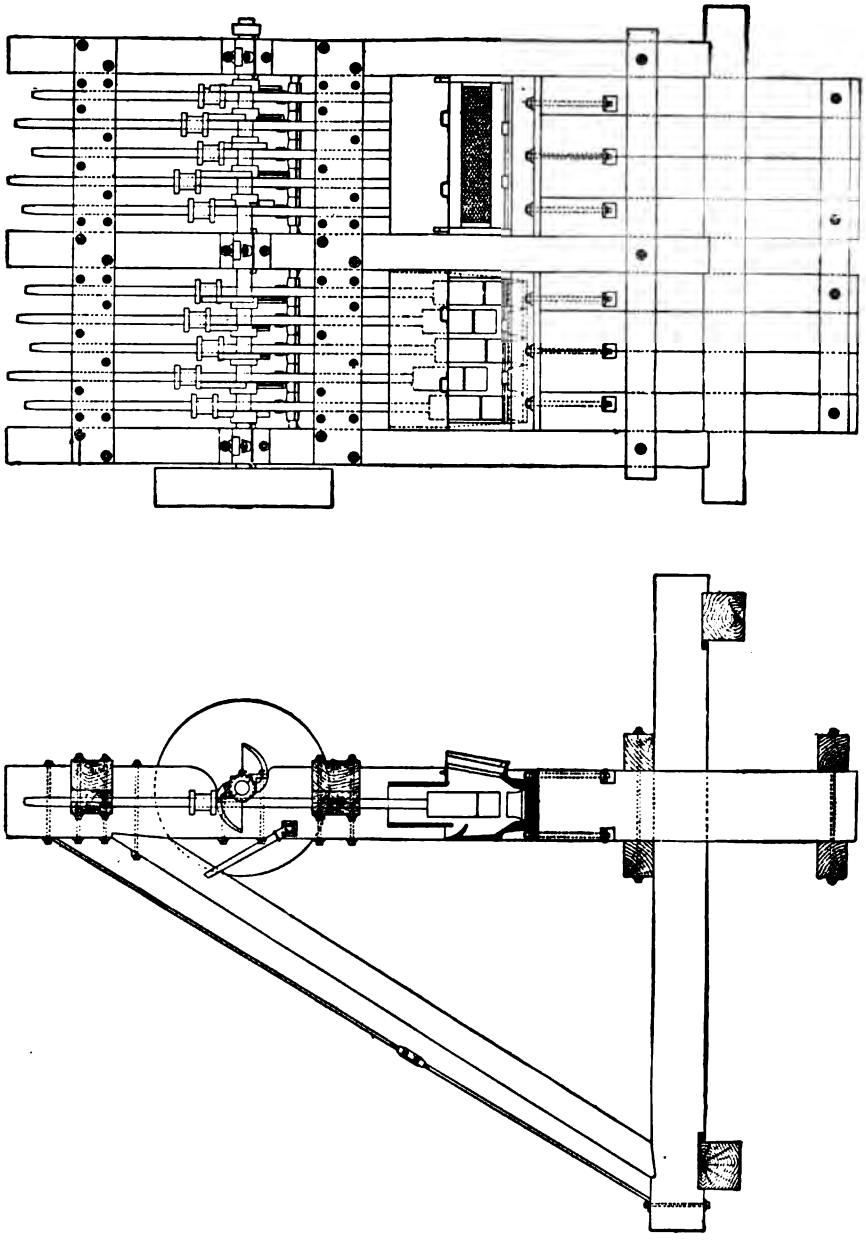

Fig. 19.—Mecklenburg Iron Works, 750-pound battery, Reimer Mine, N. C.

No satisfactory figures regarding the value of the tailings from either the concentration or chlorination could be obtained; the figures given were high as compared with those of other mines. The cost of milling, concentration, roasting and chlorination per ton of ore milled was given at $1.80 per ton. This excessive cost, almost three times as much as that at the Franklin mine, an almost identical case as far as the plant and the thickness of the ore-body are concerned, must no doubt be greatly laid to the fact that an attempt is made to supply a plant with a nominal capacity of 40 tons in 24 hours from a mine, in which the development does not warrant an output of 10 tons in this time.

The percentage and value of concentrates given above, with the addition of the gold saved on the plates, gives an estimated value of from $4 to $5 per ton to the ore mined, without including in this value the gold lost in tailings. Such an ore if found in sufficiently large bodies on developing the mine, should pay a profit with the above method of treatment under a close management.

Experiments were made with cyanide in 1896, but were not successful.

THE FRANKLIN MINE (CREIGHTON MINING AND MILLING COMPANY), CHEROKEE COUNTY, GA.

This mine is situated on the Etowah river, about 16 miles northeast of Canton, the county seat. Geologically it is in the Georgia belt. The proposition presented here is in most respects similar to that at the Reimer mine.

The country-rock consists of gneissoid mica- and hornblende-schists, often garnetiferous. The general strike is N. 55° E. and the dip 40° S.E. Granite dikes are stated to exist in the vicinity of the mine, but none have been as yet found intersecting the ore-bodies. The character of these ore-bodies has been described (p. 23). There are two parallel veins about 150 feet apart, known respectively as the Franklin and the MacDonald. Of these, the Franklin has been most extensively opened, and is the only one that has been worked during recent years. The strike and dip of the veins are, in the main, coincident with those of the country schists. The mineable ore exists in lenticular shoots or cylinders pitching 45° N.E. (see fig. 20). Four such shoots had been opened in the mine within a horizontal distance of about 750 feet on the strike, at the time of our visit. The largest one of these has a maximum length of 120 and maximum width of 14 feet. The average thickness of the ore-bodies is probably about 3 feet. All but one of the ore-shoots crop out at the surface, and they show considerable permanency in depth. The 350-foot drift in the mine was extended in a northeasterly direction about 400 feet beyond the last ore-shoot. Although a permanent vein with clay casings, and in places heavy quartz-

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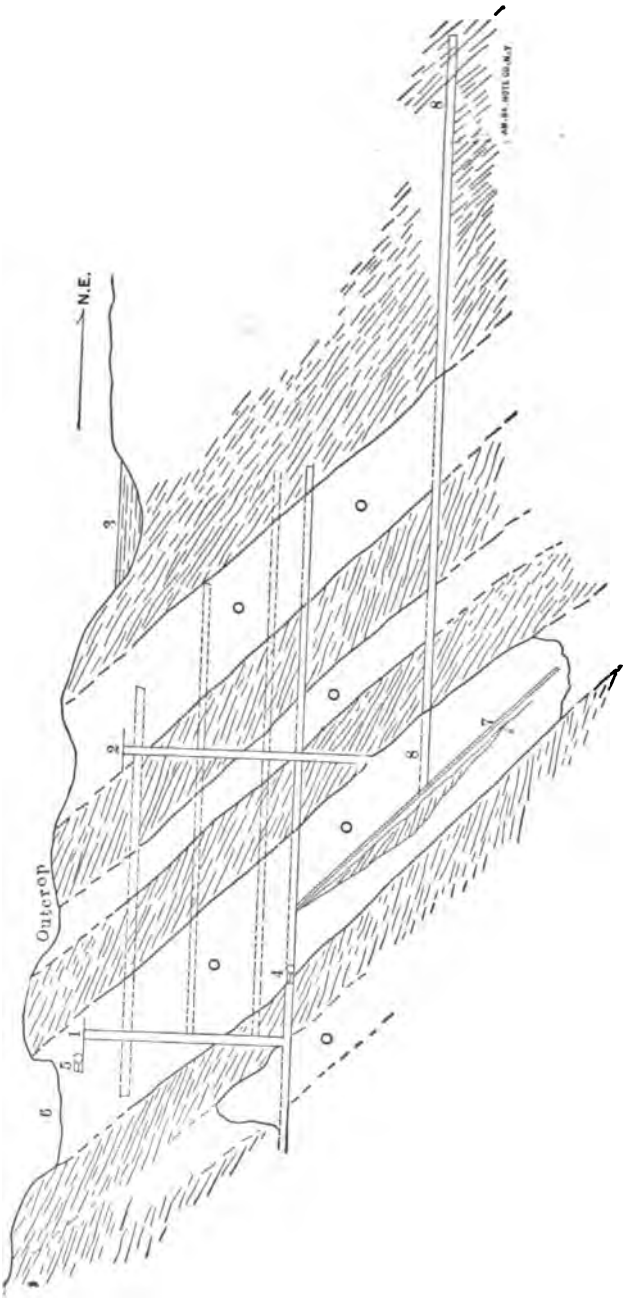


Fig. 20.—Vertical Section along the strike, Franklin Mine, Ga. Scale, 1 inch=200 feet. O, ore-bodies; 1, No. 2 shaft; 2, No. 1 shaft; 3, Etowah river; 4, underground hoisting engine; 5, surface hoisting engine; 6, Franklin Pit; 7, slope; 8, 350-foot level.

filling, had been found, the ore was not rich enough to mill. On the 235-foot level a horizontal diamond-drill hole (over 150 feet in length) was bored in the hanging, but no other parallel ore-body was found. Cross-fissures, from 3 to 6 inches in thickness, are met with in the mine, striking N. 30° to 35° W., with a vertical dip, and intersecting, though not faulting, the ore-bodies. These fissures are filled with coarse crystalline calcite, sometimes carrying inconsiderable amounts of pyrite. The structure of the vein-quartz at the Franklin is banded, and its character is milky, glassy. The sulphurets consist mainly of coarse crystalline pyrite (with very little chalcopyrite), usually occurring in bunches. Although the ore is over 50 per cent. free-milling, gold visible to the eye is of very rare occurrence. The fineness of the gold is 980 to 989.

The property of the Creighton Mining and Milling Company comprises some 1800 acres. The first work done here was by open cuts in the outcrop of the ore-shoots. After the death of Mr. Franklin, the original owner, the mine was worked for a long time by his widow.

Before the adoption of the chlorination process for treatment of sulphurets by the present company, a cyanide plant was erected and operated for a short time.

The present condition of the mine is shown in figure 20, giving a vertical section along the strike. The mine is worked entirely through No. 2 shaft (1), driven in the hanging wall to a depth of 215 feet, at which point it strikes the vein. From this level work is carried on to a total depth of 430 feet by a slope on the dip of the vein and the pitch of the ore-shoot, resting on a small horse of poor ore.

The method of mining the ore is as follows: Levels are run every 100 feet, and the ore-lenses are entirely stoped out, leaving the intervening bodies of low-grade material as pillars. The levels are connected by a series of raises, their number depending upon the length of the ore-shoots. The ore is then stoped by underhand work, the raises acting as ore-chutes (mill-holes), and the cars being loaded directly from pockets in the level below. No pillars are left below the levels, the track, when necessary, being carried over the worked-out stopes on stulls. Only such timbers as are necessary to assist the men in their work are used, the walls requiring no support. All the material stoped is hoisted and milled, leaving no waste filling in the mine. Air-drills are used almost exclusively; for stoping, a Baby Rand with $\frac{7}{8}$-inch steel is used, while drifting is done with $3\frac{1}{4}$-inch cylinder Sergeant machines. The ore is raised in cars of $\frac{1}{2}$-ton capacity, first up the incline by underground hoisting engine (4), and then trammed to the bottom of the vertical shaft, from where they are hoisted to the surface on cages. No. 1 shaft (2) is used for ventilation and as a pipe-way. The mine is not a wet one, a small steam-pump, situated immediately below No. 2 shaft, taking

care of the water. At the surface, the ore is run over a grizzly and then through a crusher, the jaws of which are set 1½ inches apart. The crushed ore is hauled to the mill by mules in cars of 1½ tons capacity, which are loaded from a bin below the crusher.

During the summer and fall of 1895 two other shafts, No. 3 and No. 4, located respectively ¼ and ¾ miles southwest of No. 2, were in progress of sinking, with the object of developing in depth lenses of ore which had been located and worked to some extent on the surface. Considerable diamond drilling has been done on the property (some 800 feet in all) at a cost of about $1.25 per foot.

The mill is situated about ¼ of a mile from No. 2 shaft, on the east bank of the Etowah river. Water at a head of 7½ feet is supplied to two turbine wheels by a dam thrown across the river. One of the turbines, a 60-inch Leffel wheel, supplies 23 horse-power to the stamp-mill, while the other, a 56-inch Davis wheel, drives a duplex Rand air-compressor. The concentrators are run by steam-power, that derived from the turbine not being of sufficient regularity to secure a uniform product. There are 20 stamps in the mill, 10 of Western make and 10 erected by the Mecklenburg Iron Works. Weight of stamps 850 pounds, 7-inch drop, 70 drops per minute, 6-inch discharge. No inside plates are used and no quicksilver is fed to the battery (a little coarse gold is cleaned from the battery sands). The screens are No. 7 slotted Russia iron, corresponding to about 30-mesh. The outside plates have the full width of the mortar. They are 8 feet long, arranged in four steps, and are handled in the same manner as those at the Haile mine. About 55 per cent. of the gold extracted from the ore is saved by amalgamation. The ore is fed from bins by Hendey automatic feeders. The mill handles 35 tons in twenty-four hours.

The pulp from each 10 stamps is carried by launders to four hydraulic classifiers, the overflow from all these going to one slime-spitzkasten of 9 by 9 feet surface dimensions. The product of the 8 hydraulic classifiers goes to 8 Embrey tables, the product of the slime-kasten being distributed to 2, making 10 tables in all working on mill-pulp. Besides these, there are 3 tables working on old amalgamation tailings, assaying about $3 per ton. The concentrates are not clean, containing about 50 per cent. of sand, but close work would decrease the percentage of extraction. The average amount of sulphurets in the ore mined is about 5 per cent., sometimes running as high as 9 per cent. As high as 5¼ tons of raw concentrates are produced and treated in twenty-four hours. The tailings from concentration run at present about 85 cents per ton, giving a remarkably high percentage of extraction.

The concentrates are roasted in two double-hearth reverberatory furnaces, with a capacity of 2 tons of roasted ore each in 24 hours. Twelve

pounds of salt per ton are added to the charge to change the carbonate of lime present to chloride.

Chlorination of the roasted concentrates is carried on in a one-barrel chlorination plant, the arrangement of the same and the method pursued being identical with that at the Haile mine (see p. 137). The tailings from the chlorination run about 60 cents per ton, giving an extraction of over 95 per cent.

Labor, Costs, etc.—At the time of our examination about 90 men were on the pay-roll of the company, when work was going on at full capacity. The force of men is variable, however, depending upon the output and the amount of development work. The wages paid were as follows:

	Per day.
Drill runners	$1.55
Helpers	1.00
Muckers	75 to 80 cents.
Trammers	1.00
Blacksmiths	2.25
Carpenters	2.50

Three men were employed on each 12-hour shift in the mill and concentration house at the following wages:

	Per day.
Amalgamator	$1.40
Concentrator	1.35
Helper	.75

Roasting.—Two men on each shift, at $1.25. Cost of roasting, per ton of roasted concentrates, $2.

Chlorination.—One man on each shift. Cost of chloridizing per ton of roasted concentrates, $1.48.

Supplies.—Timber, $9 per 1000 feet. Cord wood, $1.25 per cord, 8 cords used per day.

Cost per ton of ore mined:

Mining, crushing and tramming to mill	$2.05[1]
Milling, roasting and chlorination	.65
Total	$2.70

THE HAILE MINE, LANCASTER COUNTY, S. C.[2]

The Haile mine is situated 3 miles northeast of Kershaw in Lancaster county, S. C. It is the property of the Haile Gold Mining Company (New York office, 17 Maiden Lane), Capt. A. Thies, superintendent and general manager.

[1] This figure includes all development work. The average value of the ore and the concentrates cannot be given for private business reasons.

[2] Written in co-operation with Mr. A. Thies.

This mine represents an example of gold mining in its highest development in the South, on large bodies of low-grade sulphuret ore.

It is situated in the Carolina belt. The country is a siliceous hydromuscovite- and argillaceous-schist striking N. 45° to 70° E. and dipping 55° to 85° N.W. The rock is impregnated with auriferous pyrite, free gold, and in places small quartz-stringers. This is the mass that constitutes the ore-bodies, which are lenticular in shape. Their outline, however, does not necessarily conform with the strike and dip of the slates, but is determined rather by the degree of impregnation. The lenses are about 200 feet in length and 100 feet in maximum width. The pitch is 50° to 60° N.E., and the dip N.W. from 45° to nearly vertical. The country is intersected by a number of diabase dikes, from a few feet to 150 feet in width, striking across the slates at various angles, and in one instance (Beguelin mine) parallel with them. Where these dikes cross the ore-bodies they appear to have exerted, in some cases, an enriching influence on the ore. A short distance to the southeast of the main workings is the outcrop of a heavy quartz-vein (F., fig. 21) from 10 to 12 feet thick, which strikes parallel to the slates; it is apparently barren. As explained above, the ore consists of pyritic slates, silicified in varying degrees, from soft, sericitic slate to very hard hornstone. The more siliceous ores are usually the richest; graphitic laminæ are also good indications. In the better grade of ore the pyrite exists in a finely divided condition. Ore containing coarse sulphurets is generally of poor grade. The crucial test, however, of the value of the ore is the amount of free gold it contains, which is in direct proportion to that contained in the sulphurets, and is determined by daily panning. The ore at present delivered to the mill averages $4 per ton (assay value), of which about one-third is free gold.[1] The percentage of sulphurets in the ores varies from 2 to 25 per cent.

The first work done at the Haile mine consisted of branch washing in 1829, which led afterwards to the discovery of gold on the hillsides. All work was open cutting until 1880, when underground mining was begun, and this is continued to the present time. Although visible coarse gold is now of rare occurrence, the mine has yielded some nuggets worth from $300 to $500 from the decomposed slates in the shallow open cuts.[2]

The first mill was a 5-stamp one, afterwards enlarged to 10, and in 1881 to 20. About 1884 a Blake dry-crushing mill was erected in connection with 20 Embrey tables.[3] This was soon abandoned, and the mine was worked in a dilatory way with the 20-stamp mill until 1888.

[1] Ores as low as $2.75 have been successfully milled.

[2] *First Annual Report on the Survey of South Carolina for* 1856, by O. M. Lieber, Columbia, S. C., 1858, p. 62.

[3] "The Blake System of Fine Crushing and Its Economic Results," by T. A. Blake, *Trans. Am. Inst. Min. Eng.*, xvi, 753.

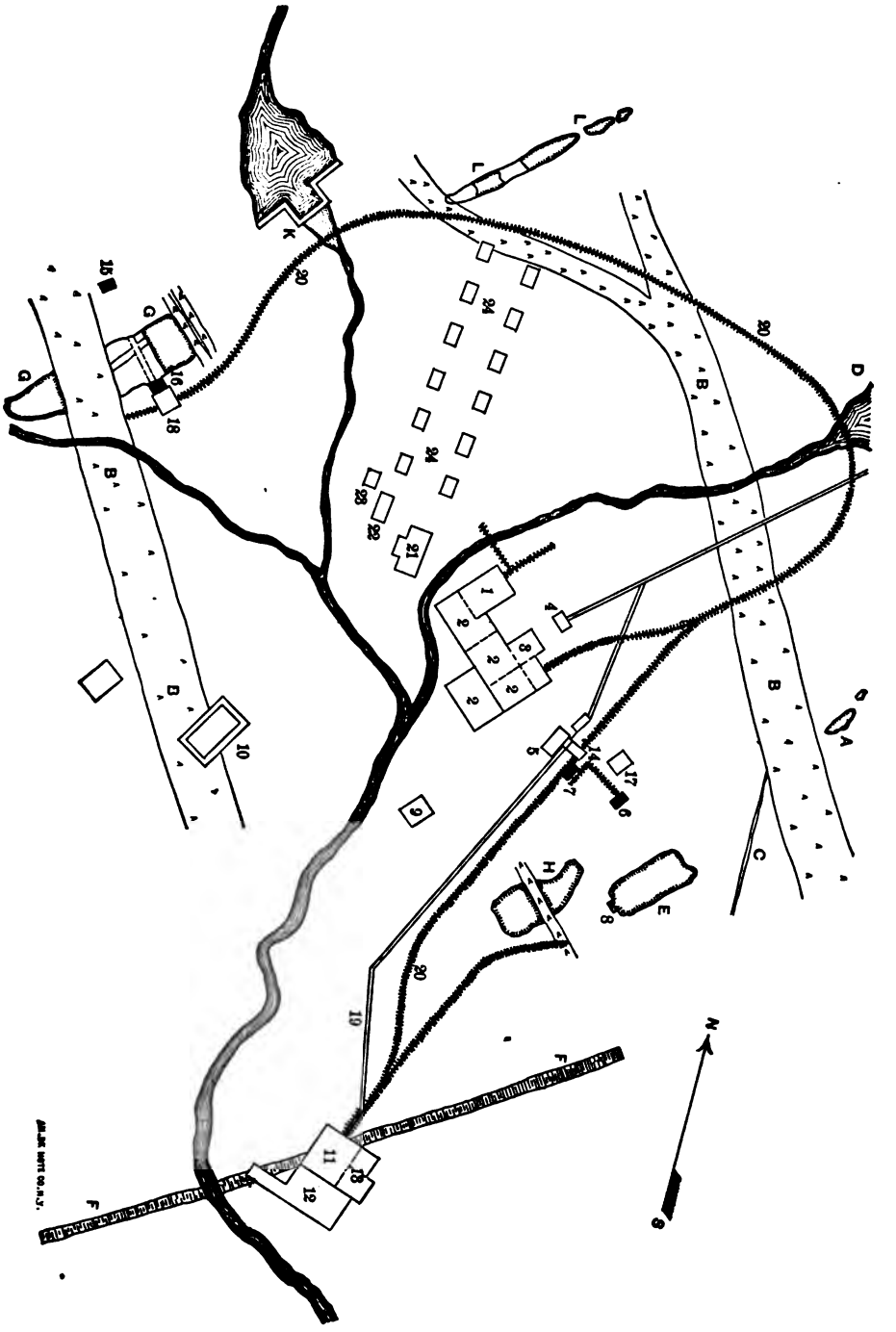


Fig. 21.—Mines and Plant, Haile Gold Mining Co., Lancaster County, S. C. Scale, 1 inch=400 feet.

A, Red Hill pits; B, Diabase dikes; C, clay dikes; D, outlet of large reservoir; E, Bumalo pit; F, quartz-vein; G, Beguelin mine; H, Haile pit; K, small reservoir; L, Chase Hill pits; 1, chlorination house; 2, roasting furnaces; 3, boiler house; 4, pump; 5, machine shop; 6, No. 2 shaft; 7, new shaft; 8, No. 3 shaft; 9, offices; 10, superintendent's residence; 11, mill; 12, concentration house; 13, boiler and engine; 14, crusher; 15, new Beguelin shaft; 16, Beguelin slope; 17, boiler house; 18, crusher; 19, flume; 20, mine railroad; 21, commissary; 22, church; 23, school; 24, village.

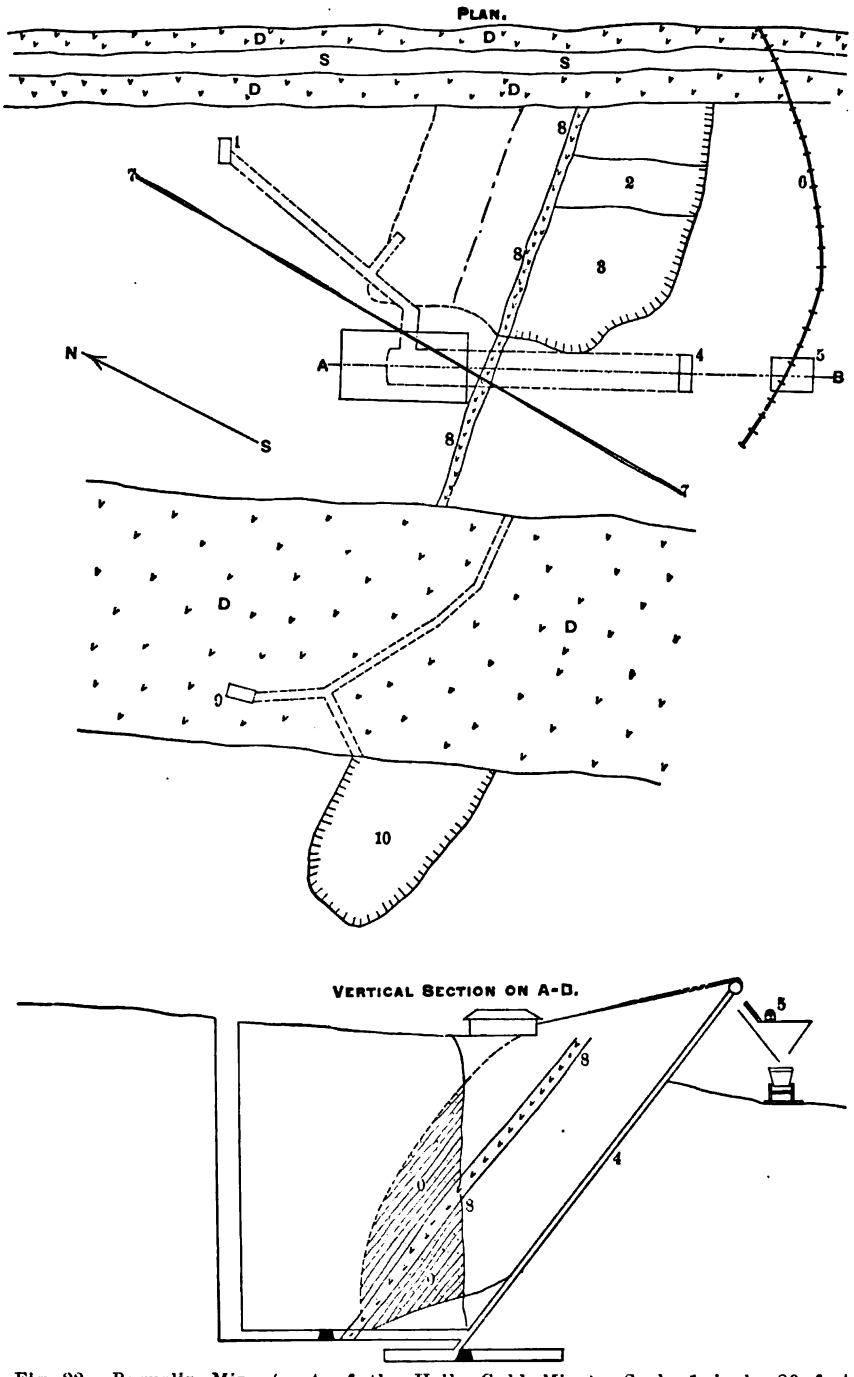


Fig. 22.—Beguelin Mine (part of the Haile Gold Mine). Scale 1 inch=80 feet D, diabase dikes; S, slate; O, ore-body; 1, new shaft; 2, pillar; 3, pit, 160 feet deep; 4, inclined shaft; 5, crusher and ore-bin; 6, mine railroad; 7, 22-inch diabase dike; 8, diabase dike, parallel to ore-body; 9, old shaft, 50 feet deep; 10, open cut, 40 feet deep.

During this time, and previously, many unsuccessful experiments for the treatment of sulphurets were made.[1] In 1888, Mr. A. Thies took charge of the Haile mine. He operated the 20-stamp mill until the mine was sufficiently developed to warrant a larger plant. At this time a 2-barrel chlorination plant was added and increased later on to 3 barrels. In 1889 the Blake mill was changed to a 60-stamp, back-to-back mill, with 20 concentrators.

DESCRIPTION OF THE MINE WORKINGS; HAILE MINE.

The present workings consist of the Cross (a continuation in depth of the old Haile and Flint pits, H, fig. 21), and the Beguelin (G, fig. 21) mines. The Bumalo, Red Hill and Chase Hill pits (E, A and L, fig. 21) have not been worked for some time, although in the first there has been considerable underground work.

Work at the Cross mine was stopped in 1888, and all attention was concentrated on the Beguelin (formerly Blauvelt) mine. Fig. 22 gives a plan and vertical section of the open pits and some of the underground workings of this mine. The old workings consist of some shallow open pits and 3 perpendicular shafts, one 70 feet deep in ore, one 54 feet deep in the diabase dike (9, fig. 22), and one 70 feet deep in the foot-wall slates on the southwest side of the dike (not shown). The first of these was transformed, from a depth of 60 feet downward, intó an inclined shaft (4, fig. 22), and sunk in the ore-body to a depth of 195 feet. This shaft was rigged with a self-dumping skip, crusher and ore-bin situated over the railroad tracks which had been extended to the mine. At 60 feet a drift was run in a northeast direction until the diabase dike was reached. Meanwhile sinking was continued in the shaft to 120 feet. From this level drifts were run and connections were made with the 60-foot level, which prepared the ground between them for stoping. At 180 feet a similar drift was run to the dike and connections made with the upper levels in such a manner that the ore from the 60-foot would fall to the 180-foot level, and from there be hoisted to the surface. At 180 feet a drift was started in a southwesterly direction, encountering at 64 feet a dike 125 feet thick, through which the drift was continued to a distance of 600 feet from the shaft. At a depth of 70 feet a similar drift was run and the ore-body beyond the dike was prepared for stoping by connecting these two drifts by several raises. At the present day all ore on the west side of the dike has been stoped out to the 180-foot level. To the northeast of the shaft a considerable body

[1] "Gold Mining in South Carolina," by E. G. Spilsbury, *Trans. Am. Inst. Min. Engs.*, xii, 99.
"Notes on the General Treatment of the Southern Gold Ores and Experiments in Matting Iron Sulphides," by E. G. Spilsbury, *Ibid.*, xv, 767.
"Chlorination of Gold Bearing Sulphides," by E. G. Spilsbury, *Ibid.*, xvi, 359.

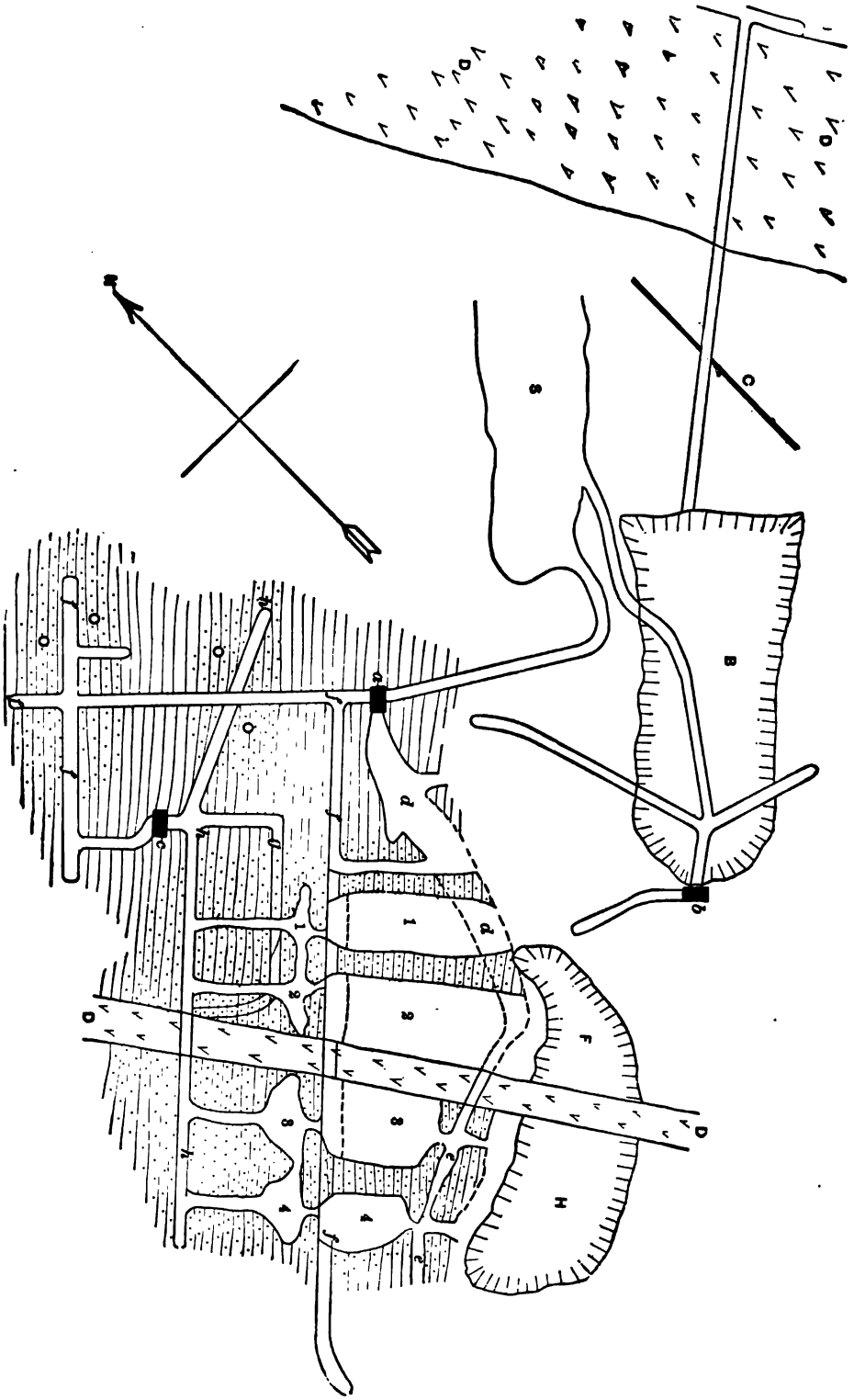


Fig. 23.—Plan of Cross Mine (part of the Haile Gold Mine). Scale, 1 inch=100 feet.

B, Bumalo pit; C, clay dike; D, diabase dikes; F, Flint pit; H, Haile pit; S, old stope, 200-foot level; *a*, No. 2 shaft; *b*, No. 3 shaft; *c*, new shaft; *d*, bottom of old stope, 160 feet, rising to 100 feet: *e*, 120-foot level; *f*, 200-foot level: *g* and *h*, 270-foot level; O, ore-bodies: 1, 2, 3, 4, stopes.

of ore was still standing above the 60-foot level. In order to extract this ore it became necessary to open the mine from the surface, and the open pit (3, fig. 22) was started. The ground was stripped to a depth of 15 feet, and from that point on the ore, though lean, was used in the mill. At 60 feet a diabase dike (8, fig. 22), lying parallel to the schistosity of the country, was encountered in cross-cutting and was at first believed to represent the hanging wall. On cutting through it, however (a distance of 4 feet), it was found to merely divide the ore-body. Under the altered conditions it became necessary to sink a new shaft (1, fig. 22) in the hanging wall as an outlet for the ore and for pumping. This shaft was sunk to a depth of 165 feet; connections were made by cross-cuts with the present inclined shaft and everything prepared for taking out the shaft pillars, as well as the remainder of the ore. This is the present condition of the mine. The maximum thickness of the ore-body at the Beguelin was 80 feet, and the best ore was found between the two large cross-dikes. A large amount of heavy sulphuretted ores is at present in sight.

Five hundred feet northeast of the Beguelin mine are several open pits known as the Chase Hill (L, fig. 21). The character of the ore at this point is somewhat different, being a banded, colored slate, barren of sulphurets, but carrying several gold-bearing quartz-veinlets. Taken as a body it will not make ore.

To the northwest of the Beguelin are several ore-leads as yet unprospected.

The 60-stamp mill was run on Beguelin ores three years. The Cross mine was then reopened (1891). A plan of the Cross mine is given in fig. 23 showing the open pits and present underground workings, as well as some of the abandoned ones. After the water had been pumped out, and the old shaft No. 2 (*a*, fig. 23), 200 feet deep, was fully secured, a cross-cut was driven in a northwesterly direction from the bottom, a distance of 25 feet. A drift (*f*, fig. 23) was started from that point in a southwesterly direction, reaching ore at a distance of 75 feet from the cross-cut. This drift, on being continued 200 feet, encountered a dike 25 feet thick, which was cut through and the drift carried on for 100 feet more. The old workings (*d*, fig. 23) were also continued through the dike, the drift (*e*, fig. 23) on the 100-foot level being run 100 feet beyond it. Four upraises were driven between these two levels, two on each side of the dike, opening up 4 large stopes of ore. This ore ran low in sulphurets, but carried more free gold and furnished one-half of the quota to the mill. In order to work the ores below the 200-foot level a new shaft (*c*, fig. 23) was sunk to a depth of 270 feet. A cross-cut was run from the bottom in a southwesterly direction for a distance of 75 feet; 15 feet from the shaft a drift (*h*, fig. 23), parallel to

the drift (*f*) on the 200-foot level, was carried in a distance of 250 feet. The dike when encountered was 35 feet thick and no longer decomposed on the wall, as was the case in the upper level, but hard and solid. By upraises 4 more stopes were opened. The ore was of a better grade in proximity to the dike on both sides.

During 1896 an open-cut was made opposite the old Haile pit, in order to take out the pillars and the ore in the hanging, above the 200-foot level.

The old workings (S, fig. 23), which were continued from the Bumalo pit (B, fig. 23), to a depth of 200 feet, and were for a long time inaccessible, have been opened up by a diagonal drift from the 270-foot level (*h*, fig. 23). Some time ago a northeast tunnel was driven from the Bumalo pit, at a depth of 50 feet and for a distance of 150 feet, to a diabase dike 150 feet in thickness, and later continued through this. Drifts on the further side showed up only barren ground, but good ore was found from the mouth of the tunnel to the dike, being richest near the dike. This ore-body was encountered in the 270-foot level with the drift above mentioned, and the ores are found to be more heavily sulphuretted than anywhere in the Cross mine.

So far as explorations have gone, 3 different lenses have been encountered: 1. The Bumalo, furthest northeast; 2. The Haile or middle lens; 3. A small lens 80 to 90 feet west of the Haile (outcrop under the new boiler-house, 17, fig. 21).

During the summer of 1896 an electric diamond-drill hole was started in back of the old store building (just to the right of 5, fig. 21). At a depth of 58 feet the cores showed ore, assaying as high as $6, and it appears as though this were in a new hanging wall lens. In order to solve this question a cross-cut is being driven on the 270-foot level along the 25-foot dike in a northwesterly direction.

Red Hill (A, fig. 21) consists of a number of open pits on the northwest side of the 150-foot dike, where ore was formerly mined to a depth of 60 feet. It is supposed to be in a line with the Haile lens.

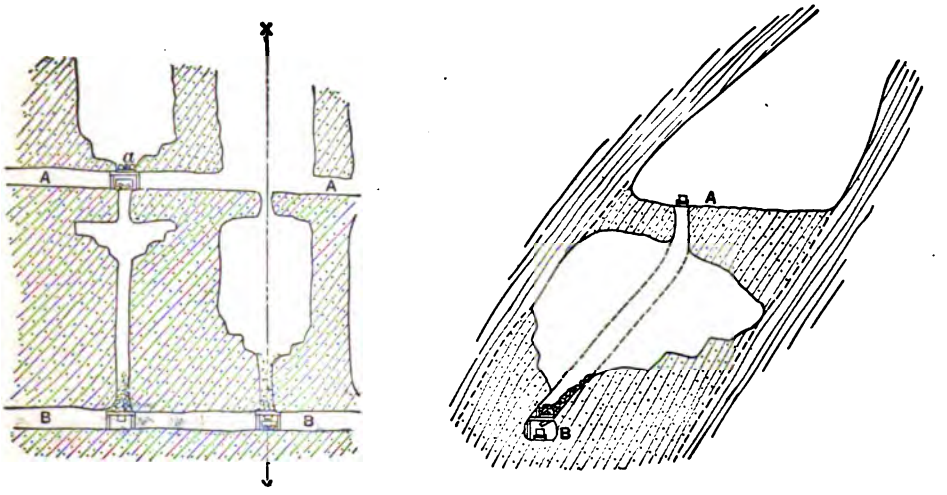
The thickness of these lenses varies, reaching 100 feet in places, while at others, near the end of the lenses, it is only from 25 to 30 feet.

METHOD OF WORKING; HAILE MINE.

The method of working these deposits is the pillar system (Pfeilerbau), illustrated in fig. 24.

The levels (8x7 feet) are run 70 to 100 feet apart, and nearer the hanging than the foot-wall. At intervals of about 50 feet upraises are made, with a cross-section of 8x7 feet. These are carried forward at an inclination as near as possible to 45°. If necessary, the upper portion through the chain pillar left under each level is carried up vertically.

This raise serves afterwards as a chute (mill-hole). Drifts are then run below this pillar until the limit of the stope in length (about 30 to 40 feet in all) is reached, leaving a vertical pillar 15 to 20 feet in thickness between the stopes. The ground is then cut away between the foot- and hanging walls, completely exposing as roof the bottom of the chain pillar above, which is sprung in the shape of an arch, with its heavier toe in the foot-wall and a minimum thickness of 15 feet. This, as well as all other work in tight ground, is done by air-drills. Stoping is then carried downward by hand-drilling in circular steps, arranged in such a manner as to allow the broken ore to drop into the chute, without further handling. The angle of 45° given to the latter allows a steady flow of



Vertical Section along Strike. Section on X-Y.

Fig. 24.—Method of Stoping at the Cross Mine (Halle Mine). Scale, 1 inch=60 feet.

the material down the foot-wall without completely choking it. At the bottom of the chute is a rough grizzly (*a*, fig. 24) made of logs, which holds back the larger boulders and prevents them from choking the smaller loading pocket below. This grizzly is easily accessible from the drift, and the larger pieces of ore are here sledged. The loading-chute and grizzly are kept up as long as possible, until the stope is finally broken through to the drift-level below, the ore being shoveled into cars. As far as possible, the pillars are left in poor ore, the diabase dike fulfilling this purpose admirably. No timber whatever is used, and although chambers 100 by 100 by 40 feet have been cut out, there seems to be no danger of a fall, the country-slate being very tough and self-supporting. The stopes from the 100- and 200-foot levels are connected with the surface by raises, so that at a future date the worked-out

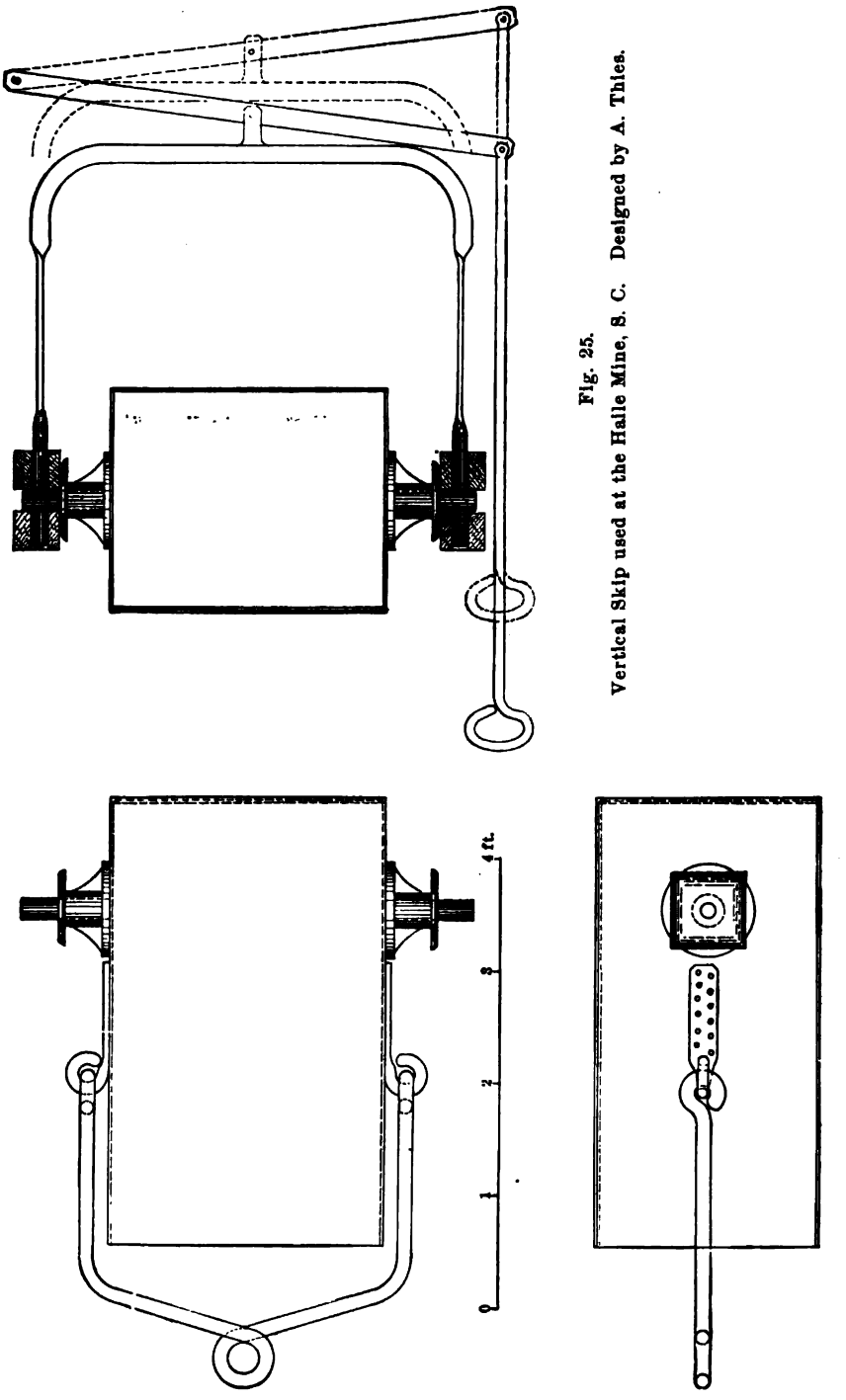


Fig. 25.
Vertical Skip used at the Haile Mine, S. C. Designed by A. Thies.

stopes can be filled from the surface and the ore in the pillars, *i. e.*, what is left toward the hanging wall, can be taken out.

Blasting is done with 40 per cent. Hercules powder. One-inch steel is used for both hand and machine-work. The number of air-drills is limited by the size of the compressor—an Ingersoll machine, with 3-drill capacity. The ore is carried from the loading-chutes to the shafts in sheet-iron cars of ¾-ton capacity, running on 18-inch gauge track. At No. 2 Shaft (7x12 feet, single compartment) they are hoisted by cage, with automatic safety catch. The new shaft is 6x14 feet, double compartment, and the ore is raised by a novel skip designed by Mr. Thies (fig. 25). The body of the skip, made of sheet iron, has two projecting lugs riveted to it below the centre of gravity and the bail is lugged one inch from the vertical centre line.

Each lug runs between a pair of yellow-pine guides set 2 inches apart. When the skip is raised above the landing-chute two iron pins are thrown across the openings between each set of guides. The skip is dropped down on these and the ore is dumped into a loading-chute placed on the heavier side of the skip. The skip is raised and righted by the bail, the iron pins are withdrawn by the lander, and the skip descends. The operation is rapid and simple and the cost of the device is light. The mine is not wet, a No. 9 Cameron pump easily handling the water.

MILLING AND ORE TREATMENT AT THE HAILE MINE.

The ore is crushed to 1½-inch size in a 10x20-inch Blake crusher at the Beguelin, and a 7x10-inch crusher at the Cross mine, and is stored at both places in bins of 30 tons capacity. The broken ore is hauled to the mill in narrow-gauge, bottom-dumping cars, holding 3 tons; 8 cars are run to the trip. The mill bin has a capacity of 300 tons, and is so arranged that every stamp can be supplied separately with ore, as, owing to the different character of the ore at the Beguelin and the Haile, it is treated in separate batteries. A hinged plate, not shown in the accompanying illustration, is for this purpose hung at the apex of the bin floor. A vertical cross-section of the mill is shown in fig. 26. Two vertical sections of a similar battery at the Reimer mine are shown in fig. 19 (p. 120).

The mill is a 60-stamp back-to-back one, 30 on each side, built by the Mecklenburg Iron Works of Charlotte, N. C. The ore is fed by Hendey self-feeders. The weight of the stamps is 750 pounds; chilled iron shoes and dies are used; the stamps drop 6 inches, 86 times per minute, in the order 1, 3, 2, 5, 4. The crushing capacity is 2 tons to the stamp in 24 hours. The screens are 30-mesh, made of No. 20 brass wire; these work well if no cyanide is used in the battery. The average height of

discharge is 6 inches. Amalgamation is accomplished: (1) In the mortar by a curved front plate attached by means of a wooden chuck-block to the lip of the mortar, immediately below the discharge; it is held in position by bolts and can be rapidly and easily removed. It presents an amalgamation-surface of 1.75 square feet and is made of No. 7 silver-plated sheet-copper. The gold being very fine, its accumulation in the mortar between the dies is insignificant, and the mortar is seldom cleaned

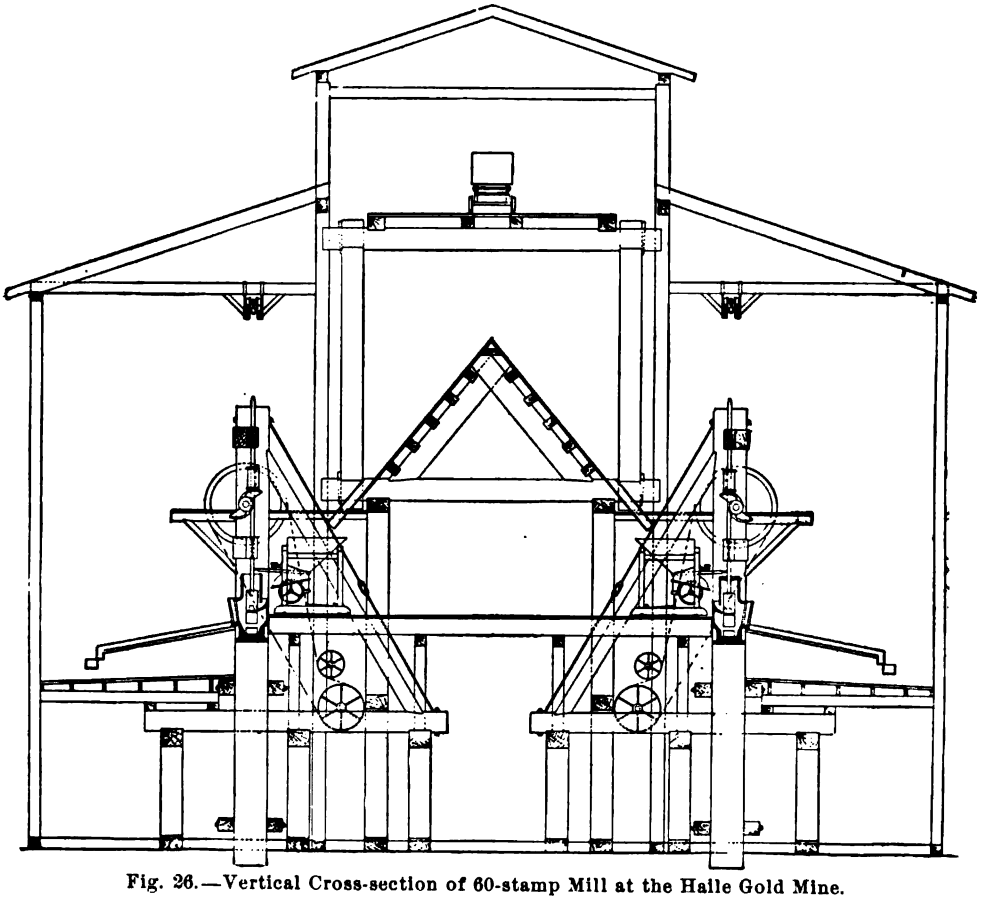


Fig. 26.—Vertical Cross-section of 60-stamp Mill at the Haile Gold Mine.

out. (2) On the outside plates, made of No. 12 silvered copper-sheet, and presenting an amalgamation-surface of 32 square feet to each battery of 5 stamps; they are the full width of the mortar and are arranged in four steps, each 2 feet in length, and overlapping the next by 1 inch, the inclination being 2 inches in 1 foot. They are fastened directly to the battery, the tremor caused hereby being considered beneficial to amal-

gamation. These plates are interchangeable; whenever the upper plate becomes hard and unfit for amalgamation, it is interchanged with one of the lower plates, thus giving in rotation to each plate a position at the head of the table. The outside amalgamation-surface of each battery is further increased by 12 additional square feet, arranged by a drop system of three plates, the pulp discharging from one to the other before it enters the main launder. Each battery is provided at the screen-discharge with an impact-plate, not only for amalgamation, but to retard the velocity of the pulp. They are cleaned from verdigris with a weak solution of cyanide, and a little potash is sometimes fed into the battery. Phosphate of sodium is used in the mill to keep the quicksilver bright and lively. It has been found expedient to remove the inside plates every 24 hours; as duplicate plates are kept on hand, no delay occurs while they are being cleaned. The amalgam from these, which is collected and weighed daily, forms an excellent indication of the value of the ore milled. The amalgam is removed from the outside plates whenever it is necessary. A regular clean-up is made only once a month. About one-third of the gold is saved on the inside plates. The fineness of the mill gold is 880. The average amount of water used per stamp is $3\frac{1}{2}$ gallons a minute; and the average consumption of quicksilver is 0.35 ounce per ton of ore. The wear of shoes and dies is 1.3 pounds per ton of ore stamped. As a lubricant for the cams, molasses thickened with flour is used and gives excellent results.

The pulp is carried to the concentrators in launders lined with riffles for a distance of eighty feet. No attempt at sizing the pulp is made, but the ores from the Beguelin and Cross mines, owing to the difference in contents of sulphurets, are concentrated separately. The Cross ore averages about 2 per cent., the Beguelin running from about 7 to 25 per cent. sulphurets. They are milled separately in the proportion of $\frac{4}{10}$ Beguelin and $\frac{6}{10}$ Cross, so as to obtain an average of 7 to 8 per cent. sulphurets from the total ore milled. The concentration is done on 20 Embrey tables (4 by 12 feet), with smooth rubber belts which are set at an inclination of $2\frac{5}{8}$ inches and travel 5 feet per minute, receiving at the same time 192 percussions. The concentrates contain 90 per cent. pyrite, which is pure sulphide of iron with occasional small traces of arsenic. The loss in concentration is 15 to 20 per cent. The average value of these concentrates is $25 to $35 per ton.

Chlorination.—The concentrates are hauled on the mine-railway to the chlorination plant. They are roasted in two double-hearth reverberatory (see fig. 27) and one revolving pan-furnace, the sulphur being reduced from about 43 to as low as $\frac{1}{4}$ per cent., and the value of the material being increased by $\frac{1}{3}$. Each double-hearth furnace is worked by two men to a shift of 12 hours, the output being 2 tons of roasted

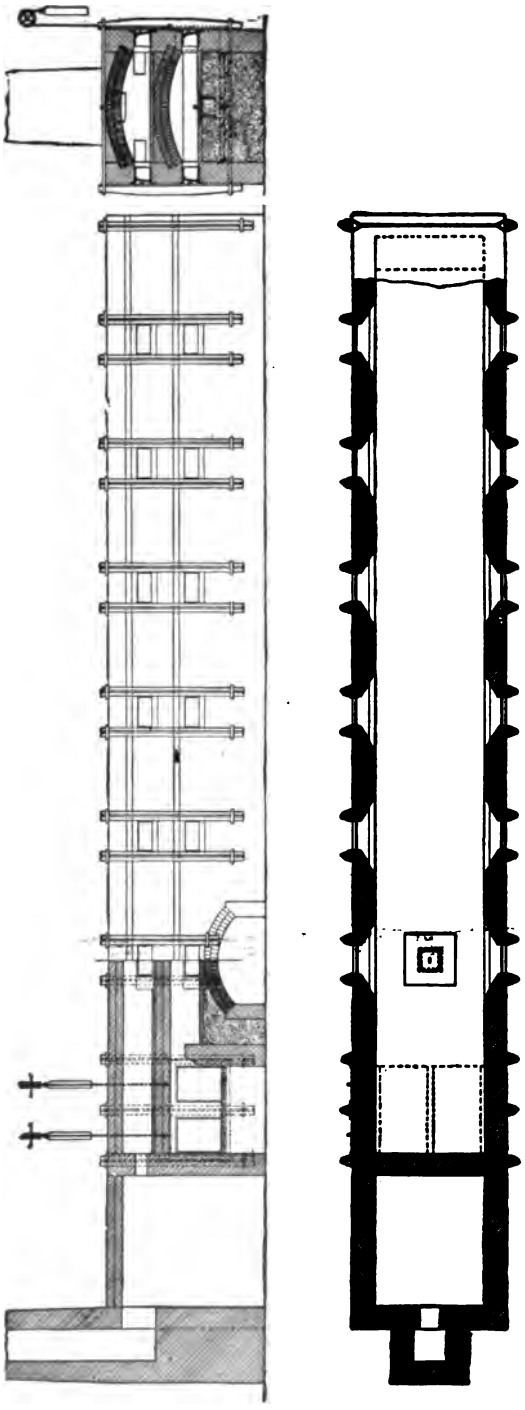


Fig. 27.—Double-Hearth Roasting Furnace; Chlorination Plant; Haile Gold Mine. Dimensions of hearth: 5 feet wide by 40 feet long. The upper figure represents a vertical, and the lower a horizontal section of the furnace.

concentrates per 24 hours for each furnace. The revolving pan-furnace is worked by three men per 24 hours, with the same output as the double-hearth. The fumes from these furnaces carry off into the air the equivalent of 13 tons of 50 per cent. sulphuric acid. The management has investigated the erection of lead chambers, but so far have not considered such an installation to their advantage. The Spence furnace has

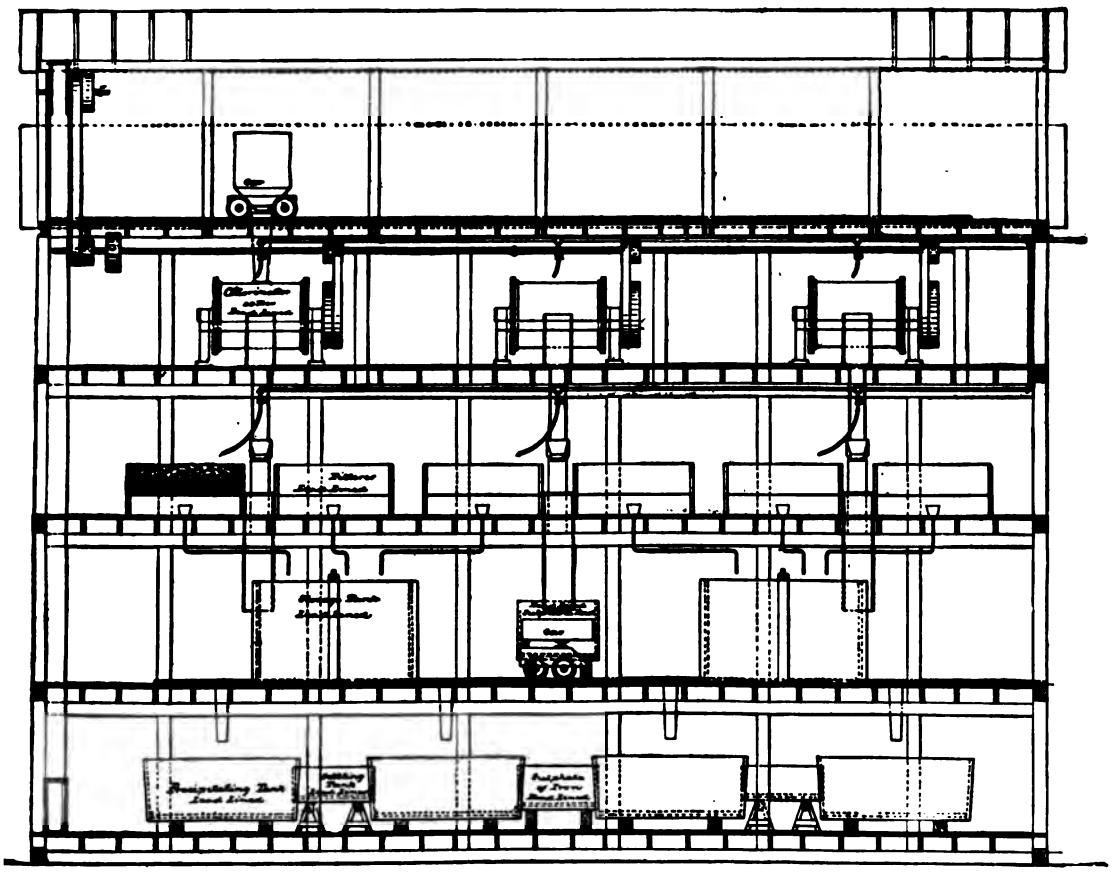


Fig. 28.—Chlorination plant at the Haile Gold Mine. Vertical Longitudinal Section.

been tried at the Haile, without success.[1] The roasted ore after cooling is elevated to the top floor of the chlorination house, 32 feet high. This consists of a four-story frame building, containing 3 chlorination-barrels, 11 filtering-tanks, 2 storage-tanks, and 13 precipitating vats (see figs. 28, 29). The ore is charged through a hopper into the chlorination-

[1] See paper by A. Thies and W. B. Phillips, "The Thies Process of Treating Low-grade Auriferous Sulphides at the Haile Gold Mine, Lancaster Co., S. C.," *Trans. Am. Inst. Min. Eng.*, xix. 601.

barrels (see fig. 30) by cars holding 1 ton each. The barrel is 60 inches long by 42 inches in diameter, made of cast-iron and lead-lined (12 pounds of lead to the square foot). It also contains a lead valve in order to ascertain whether the necessary amount of free chlorine is present. (The use of this valve is unnecessary after the character of the ores becomes known).

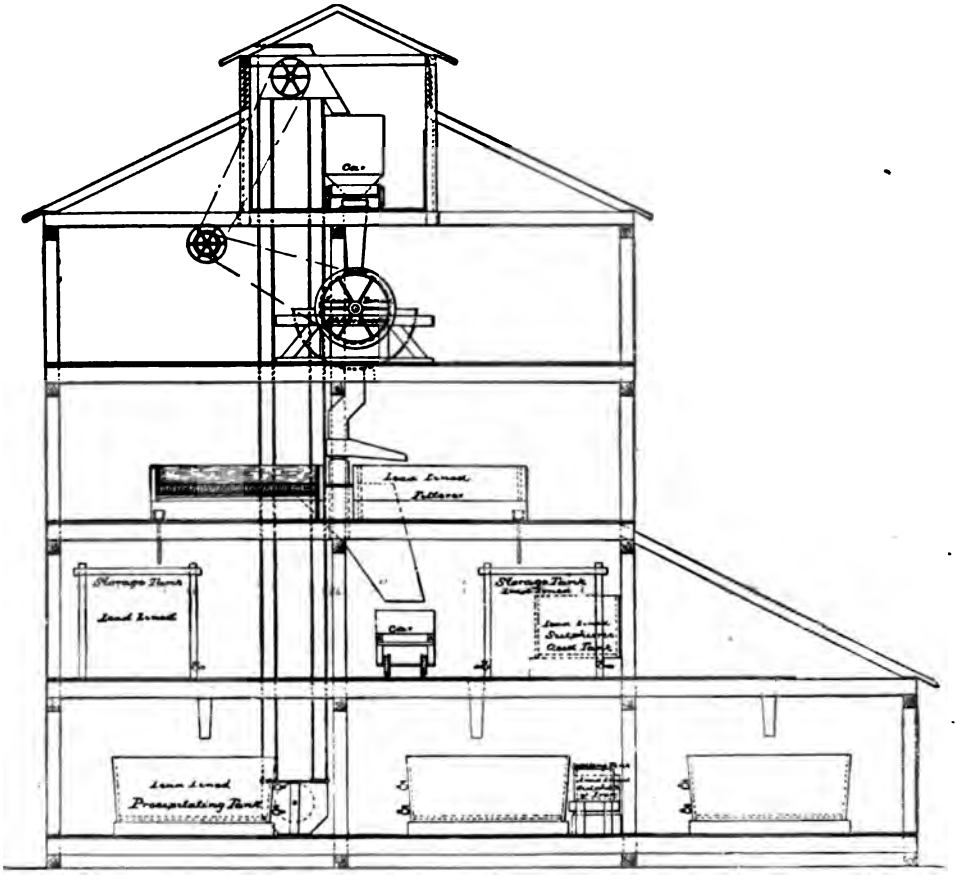


Fig. 29.—Chlorination Plant at the Haile Gold Mine. Vertical Cross-section.

The full charge consists of 120 gallons of water (to make an easily flowing pulp), from 8 to 11 pounds of bleaching powder, then the ore, and finally 12 to 15 pounds of sulphuric acid. The barrel is hermetically closed and revolves for about 3 hours at the rate of 15 to 18 revolutions per minute. (A 5 horse-power engine performs this work and also the elevating of the ore.) The barrel is then inverted, opened and discharged through a lead-lined semicircle in the floor to a filter on the

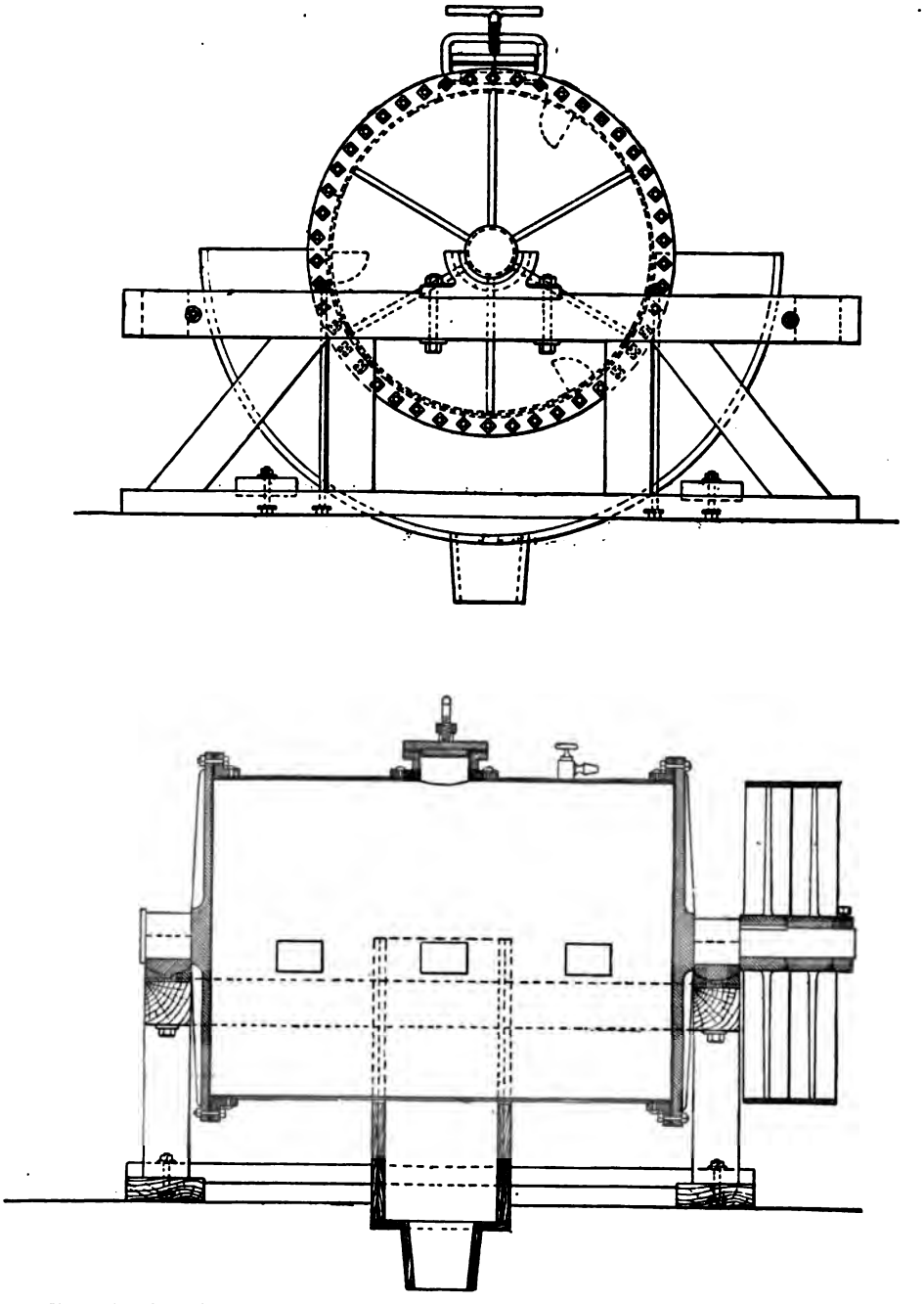


Fig. 30.—Chlorination-Barrel, Haile Gold Mine. The upper figure is a vertical cross-section, and the lower a vertical longitudinal section. Inside dimensions: Diameter, 42 inches; length, 60 inches.

floor below. There are 4 lead-lined filters to each barrel, their sizes being 6 by 8 feet by 18 inches deep in front and 17 inches in back. The bottom is covered with mineraline[1] tiles 12 by 12 inches by 1 inch thick, perforated and having ½-inch gutters underneath; on top of these is placed a rack of 1¼-inch wooden slats, 4 inches high and 8 inches apart; the first layer above the tiles consists of 4 inches of coarse quartz pebbles (⅛ to ½ inch size), and this is covered by from 1 to 2 inches of ordinary clean sand. Before emptying the contents of the barrel, the filter is flooded with water to the level of the top of the filter-bed to act as a cushion. Then the original solution is passed through, striking on a float to prevent breaking the filter-bed. The ore-pulp is washed twice with clean water; the first time enough is added to stand 4 inches above the surface of the pulp, and the second time the tank is entirely filled.

This amount is found sufficient to thoroughly remove all traces of chloride of gold from the pulp (tests are made with $FeSO_4$). The filtered solutions are stored in two stock-tanks on the second floor, and are drawn off from these into the precipitating-tanks as required. The latter are 8 feet in diameter and 3 feet high, made of wood, the interior coated with asphalt. They are provided with three outlets, the upper one 18 inches from the top, the middle one 1 inch above the bottom and the lowest one in the jamb. The gold is precipitated in the metallic state with an excess of fresh ferrous sulphate, made in a small lead-lined tank. In warmer weather 48 hours suffice for settling, and in colder weather from 3 to 4 days. The supernatant liquor is drawn off through the two upper outlets, opened one after the other (in order to prevent any stirring of the precipitates), and passed through a box filled with sawdust to catch any precipitate. The gold precipitate is drawn from the tanks through the jamb-opening into a small lead-lined settling-tank 2 by 2 by 4 feet. After standing 24 hours the supernatant liquor is siphoned off, and the precipitate filtered on paper. This is dried and mixed with about half its weight of borax and soda in almost equal proportions. Should iron salts be present, a little quartz sand is added. It is melted in graphite crucibles and cast into ingots of about 990 fineness. The whole operation is so simple that the most ordinary laborer can acquire the mechanical knowledge in a day. The repairs are practically *nil*.[2]

LABOR, COSTS, ETC., AT THE HAILE MINE.

Some of the figures of costs of labor and working at the Haile mine are given below. For private business reasons it is impossible to give these as fully as we should like to.

[1] A melted mixture of sulphur and quartz.

[2] The Thies chlorination process has been described in detail by T. K. Rose, in his *Metallurgy of Gold*, C. Griffin & Co., London, 1894.

Mines.—Cost of Labor:

	Per day.
Holders	$ .90
Strikers	1.10
Machine-runners	1.25

255 cords of wood at $1.50, burned per month.

Mill (2 shifts of 12 hours each).—Distribution and Cost of Labor:

One superintendent	$
" laborer (amalgamation) per shift	2.50
" " " "	1.00
" " (concentration) "	1.25
" " " "	.80
" fireman per shift	1.00
" engineer per day shift	1.75
" " per night shift	1.50

150 cords of wood at $1.50, used per month.

Repairs (wear of shoes and dies, etc.), 4 cents per ton of ore.

Roasting and Chlorination.—Distribution and Cost of Labor:

Roasting furnaces, producing 6 tons of roasted concentrates per 24 hours; six men, day shift, each	$1.00
Five men, night shift, each	1.00

3 cords of wood at $1.50, used per 24 hours.

Chlorination (1 shift of 12 hours) working 6 tons of roasted concentrates:

Two men, each at	$1.00
One man at	1.25

Cost of roasting per ton of roasted concentrates:

Labor	$1.83
Fuel	.75
	$2.58

Cost of chlorinating 1 ton of roasted concentrates:

Labor	$ .50
Foreman	.20
Power	.12
Sulphuric acid for $FeSo_4$	.06
11 pounds of bleaching powder, at 2½ cents	.27½
15 pounds of sulphuric acid, at 1 cent	.15
Wear and tear	.10
Superintendence	.05
	$1.45½

Cost of roasting and chlorination per ton of raw concentrates	$3.02
Cost of roasting and chlorination per ton of ore mined	.19

Percentage of Extraction:

Mill: Tailings from concentrators	85 to 90 cents.
Showing a yield of	75 to 80 per cent.
Chlorination: Tailings as high as	$1.50
Average yield	94 per cent.

THE BREWER MINE, CHESTERFIELD COUNTY, S. C.

The Brewer mine (the De Soto Mining Company) is situated on Lynch's creek, about 13 miles by road northeast of Kershaw, the nearest railroad station; it is about 8 miles (air-line) northeast of the Haile mine.

The mining problem presented here is the working of large bodies of low-grade, sulphuretted ores by quarrying, milling, concentration, and chlorination.

Geologically, the mine is situated in the Carolina belt. The country-rock is a hard, devitrified acid volcanic (probably quartz-porphyry), of a light bluish-gray color, resembling hornstone or chert. It is in part sheared into sericitic schists, similar to the slates at the Haile mine, though more highly silicified. Masses of coarse, pyroclastic breccia were found in the bottom of the large mine-pit, but the rock was not observed in place. The strike of the siliceous schists is very much confused, being in all directions; the normal strike is probably something like N. 70° E., and the dip 60° N.W. Numerous coarse-grained granitic dikes (G, fig. 31) intersect the country, and the local abnormal strikes and dips of the schists may be due to their intrusion. These rocks occupy an elevation known as Brewer hill, which rises some 200 feet above the level of the main drainage basin, Lynch's creek on the east and Flat creek on the west. A heavy diabase dike lies on the west bank of Flat creek, and to the west of that, the country-rock is granite.

The ore-bodies at the Brewer are similar to those of the Haile mine, being auriferous pyritic impregnations in the country-rock, and assuming more or less lenticular forms. Free gold appears as thin films or coatings on the cleavage- and joint-planes of the schists. The ore-bearing rock is decomposed, in certain streaks more than in others, to the deepest workings of the mine, 150 feet, resulting in soft, friable masses which disintegrate into finely divided white sand. Certain portions of the deposit are richer in gold, and these also have an imperfect lenticular shape, from 10 to 30 feet in thickness (O, fig. 31). These better grade ores will run from $5 to $7 per ton, assay value, while the average run of the mine is in the vicinity of $3. The fineness of the gold is from 970 to 984. The total width of the ore-bearing ground is stated to be 800 yards. The main ore-body has been opened for a distance of 600 feet in a north and south, and 250 feet in an east and west direction. The sulphuret contained in the ore (finely divided pyrite) averages about 7 per cent of the total mass. In one portion of the mine enargite (and perhaps also covellite) appears in some quantity, but its occurrence is local. Other sulphurets occur in small quantities, but are interesting merely from a mineralogical standpoint. Tinstone (sometimes in direct association with gold) has been found in hydraulicking

at the Tan-yard deposit; and pyrophyllite occurs as an alteration product in the granitic dikes.

The ore itself is practically devoid of auriferous vein-quartz. Small reticulated fissures filled with barren quartz intersect the country; and in the Tan-yard (an old gravel-channel to the east of the mine) a large barren quartz-vein, 5 to 20 feet in thickness, is to be seen.

The Brewer mine, probably one of the first developed in South Carolina, was opened in 1828 by shallow pits in the saprolites and in the gravels of the Tan-yard, the material being worked in rockers. This work continued until 1857, and it is stated that in various years during this period as many as 100 to 200 hands were employed at one time, making $1.50 to $3 per day each, and paying nearly 30 per cent. royalty. From 1857 to 1862 Commodore Stockton mined and milled the ore in arrastras and Chilian mills. Up to 1879, when the Brewer Mining Company took hold of the property, there seems to have been a lull in the activity of the operations. In this and succeeding years the old Tan-yard placer was reworked by hydraulicking. This deposit is an old river-channel, and was extensively worked in former days, being, in fact, the site of the first discovery of gold on the property. The width of the channel is from 200 to 300 feet, and its length about 1½ miles; it is now intersected by a large valley. The original overlay was about 6 feet, and the gravel from 3 to 6 feet in thickness, underlain by a thin bed of compact conglomerate, cemented by iron oxide; the bed-rock is a siliceous sericitic schist. The old miners in working this deposit did not wash the overlay, nor did they take up any part of the bed-rock. In reworking, the whole mass (from 5 to 20 feet in thickness) was hydraulicked, and as much as 4 to 5 feet of the loose bed-rock was also torn up. Water was pumped about 200 feet in vertical height, from Lynch's creek to a small reservoir situated at the head of the placer, from where a portion of it was delivered to the giant (2½-inch nozzle), by a force-pump under a pressure of 80 pounds, and the remainder run directly through the ground-sluices to carry off the tailings. Six men were employed in cleaning bed-rock, and two at the sluices. It is stated that a handsome profit was realized by this work.

In 1885 a 5-stamp mill was erected and run on ores produced in prospecting work. In 1887 an adit-level (A, fig. 31), 1200 feet in length, was driven into the hillside under the main ore-deposit, and the mine was opened from below by a raise, which was at the same time used as a chute, connecting with the open pit above. The stoping was carried on overground, and the material taken out through the tunnel. In 1888 a 40-stamp mill was erected, and started up in May, 1889. A Thies chlorination plant was added in 1892, and operated for a short time during 1893. From that date until June, 1895, the mine was idle, but at that time preparations were being made for starting work again.

Figure 31 represents the plan of the Brewer mine as it is at present developed. It consists of the large open pit (P), 150 feet in depth, about 200 by 250 feet on the surface, and 100 by 180 feet in

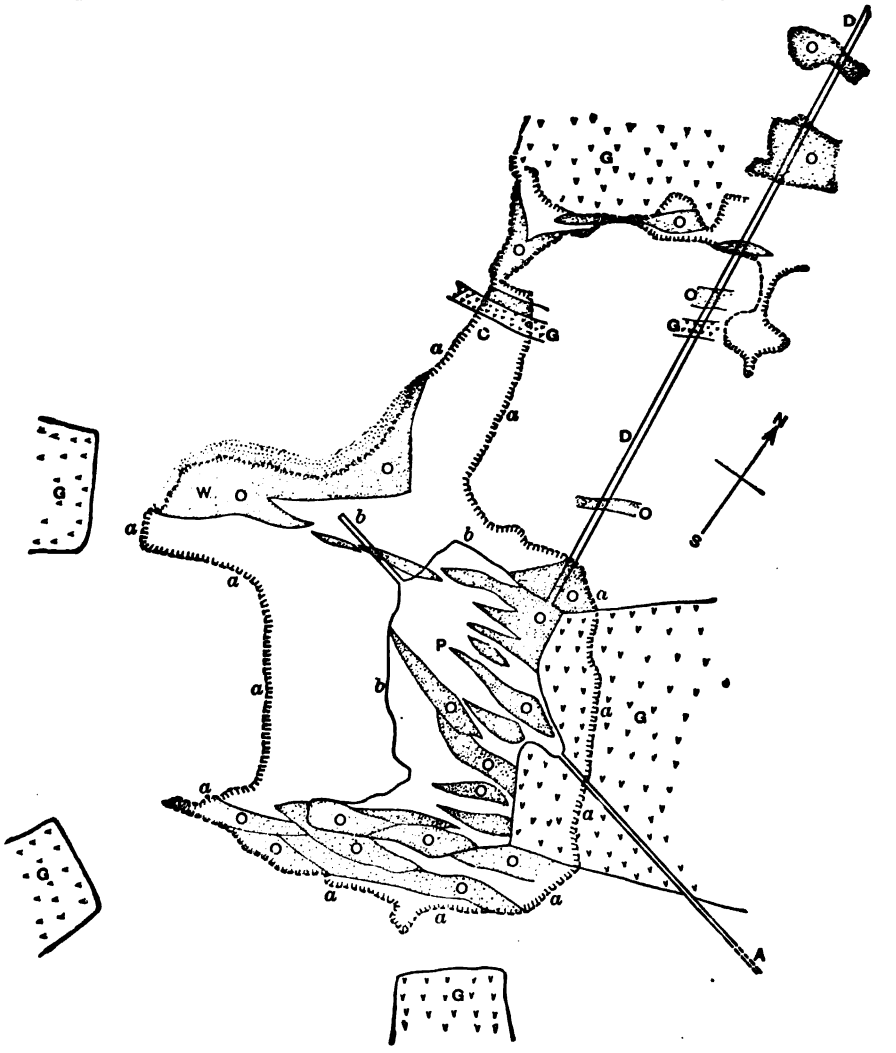


Fig. 31.—Plan of Brewer Mine, Chesterfield County, S. C. Scale, 1 inch=120 feet A, adit-level, 1200 feet long; C, north cut, 40 feet deep; D, drift, 150-foot level; G, granitic dikes; O, streaks of best ore; P, bottom of main pit, 150 feet deep; W, west cut, 50 feet deep; *a a*, surface line of open cut; *b b*, 150-foot level.

the bottom. The ore-body has been further explored by a drift (D), on the bottom level, extending 430 feet in a northerly direction, and being in ore all the way. The tunnel (A) is laid with narrow-gauge

FORTY-STAMP MILL AND CHLORINATION PLANT, BREWER MINE.

track, over which the ore is hauled to the mill by a small locomotive. This tunnel is drained by a wooden gutter situated in the center of the track line. At present ore is being quarried in the west cut (W) near the surface, from where it falls to the bottom of the pit (P), and is hauled to the mill through (A). The 40-stamp mill, which was not in operation when visited, is situated about a quarter of a mile east of the mine, on the west bank of Lynch's creek. It is of the Western type, built by Fraser & Chalmers. The weight of the stamps is 900 pounds. The mortars are 15 inches wide at the lip, and are fitted with front inside plates and 30-mesh steel wire screens. The outside plates of silvered copper are 8 feet long by 54 inches wide. Below the plates is situated a line of pointed boxes, serving simply as amalgam-traps, which discharge 2 feet above the bottom to four Frue vanners with 6- by 14-foot belts. This is one of the most substantial and best constructed mills in the South. (Plate X.)

The chlorination plant consists of 2 revolving-pan furnaces, 2 barrels, 8 filters, 2 stock-tanks, and 8 precipitating-vats of the same construction and arrangement as at the Haile mine (see pp. 139–142).

When the mill was last operated (in 1893), the object was to put through as much material as possible; 5 to 6 tons of ore per stamp were milled in 24 hours, with 4-inch drop, 90 drops per minute, crushing through a 20-mesh screen. Naturally, the pulp flowed over the plates without a large portion of it coming in contact with them; and, with only 4 vanners, the ultimate loss in tailings was so great as to leave little if any profit. The concentrates that were obtained ran from $15 to $20. About 50 per cent. of the gold in the ores is free, and of the amount saved in amalgamation 50 per cent. was in the battery and on the inside plate. The cost of mining and milling at the Brewer mine, as practiced above, is given at 75 cents; and the total cost (including maintenance, salaries, etc.) at $1 per ton of ore mined.

Laboratory experiments with cyanide, and others with chlorination in bulk (the latter by Mr. P. G. Lidner), have been tried at the Brewer, but proved unsuccessful. In the latter part of 1895 cyanide experiments were again undertaken with reported favorable results.

CHAPTER VII.

SOME CONCLUSIONS CONCERNING GOLD MINING IN NORTH CAROLINA AND ADJACENT SOUTH APPALACHIAN REGIONS.

Bonanzas, in the general meaning of that term, have not been found in North Carolina nor in the adjacent South Appalachian regions, and probably never will be, unless we except rich pockets of limited extent which for a time might prove to be such to the individual operator or tributor. The Western saying that "A good gold mine is one which will pay dividends under poor management," would exclude all Southern gold mines from even this distinction. There are, however, a few mines in the south, notably the Haile and the Franklin, which, under able management, fully conversant with all the requirements and exigencies of the case, have been developed into remunerative business enterprises. The wide distribution and the variety of the auriferous deposits throughout the South do not preclude the possibility of these mines serving as examples for a larger number of operations, instead of being isolated cases as at present.

By far the greater portion of the gold that has been produced in the South was derived from the placers, including bottom and sidehill gravels, as well as auriferous saprolites and decomposed vein outcrops. From such deposits the cream has been worked off, and what remains are the old gravel heaps and such virgin ground as in the earlier days proved inaccessible to water and unprofitable for primitive methods, or was overlooked by the prospectors. Of the latter class the Crawford mine, described on pp. 91–95, is an example. Although the earlier prospecting for gravel deposits was carried on in a thorough manner, there were no doubt large plantations on which such work, especially in the fertile bottoms, was not countenanced. It is also probable that deeper lying gravel-channels, of which there are no indications on the surface, remain to be exploited, as, for instance, in the South Mountain and Dahlonega districts. The installation of pumps (or where these have been unsuccessfully used, the erection of improved or more economic plants), as well as more thorough and extensive surveys for ditch lines, may open up much ground which was formerly inaccessible to water. Hydraulicking under direct pressure from a pump may in many cases be feasible, and may prove more economical as far as plant is concerned.

Bottom-gravel mines were operated in the earlier days almost entirely by pitting, draining the excavations with water-wheels, and raising the gravel by hand to rockers and sluice-boxes, the tailings being left in large heaps. This work was often done in an unsystematic manner; portions of the ground could not be worked at all; and, in general, only the richest gravel received attention, the overlay and the bed-rock being neglected entirely. Some of these gravel heaps have frequently been reworked, in one case (on the Mills property, N. C.) as often as seven times. The additional gold obtained in these operations was partially due to the incompleteness of the preceding washings, as well as to the subsequent further disintegration of vein-quartz carrying free gold and sulphurets. A number of these old bottom-placers may warrant a remunerative reworking on a large scale, either by the use of giants and bed-rock sluices when sufficient fall is available, or where the latter is not the case (a common feature in the South) by the application of the hydraulic gravel-elevator.

Virgin placer deposits also exist, which, on account of the low grade of gravel, or the great depth of the overlay, could not be profitably worked by the more primitive methods. For such, the above appliances may also furnish a solution. The Southern gravel deposits are far less extensive than those of California and New Zealand, and therefore as low a grade of gravel cannot be worked, although the South has cheaper labor in its favor. Systematic work has rarely been pursued, and records of such work have not been kept. For this reason, as well as on account of the unequal concentration of the gold in the deposits and the varying working conditions met with, it is impossible to give limiting values per cubic yard to guide operations in the future. For the same reasons, preliminary testing will be difficult, especially in ground that has already been worked.

In general, it may be said that the great extent of the rock-decomposition in the South (often from 25 to 100 feet in depth), and the easy disintegration of the same has resulted in a greater concentration of gold in the gravel, considering the richness of the ore-bodies in place, than in many other gold fields.

The auriferous saprolites and decomposed vein-matter have been most extensively worked in the Dahlonega district. Here the decomposed material, in which gold from the eroded vein-matter is more or less concentrated, has to a great extent been worked down to the harder rock. In the Dahlonega method of working, everything seems to have tended towards the simplification of the process and plant, with the object of milling as large an amount of low-grade material as is possible with economy in labor and plant, irrespective of close working. Both on account of the greatly impoverished material and its increasing unfitness

for disintegration with the giant, a limit to this method of mining must ultimately be reached here. The ore-bodies continue in depth and should open up a probably more productive field in deep mining, with less loss of gold and more economical output.

Although the Southern gold field has been known and worked since the beginning of the century, it has not had the benefit of such thorough and systematic vein-prospecting as most of the later discovered fields. It was already a well-settled farming country, generally owned in large plantation-tracts, when gold was first sought after; and such lands as were unoccupied were the property of the State governments, which did not offer special privileges and inducements to the development of the mining industry. Hence the Western system of mineral lands and mining claims did not exist, and the field was not opened to the individual professional prospector. The same condition practically exists to-day. It is difficult to make satisfactory arrangements with the property holders for prospecting; and propositions for such work from outsiders are as a rule regarded with suspicion. Even the larger tracts owned at present by mining companies have not been prospected to any extent. A notable exception to this is the development work carried on by the Yonah Land and Mining Company in Georgia. If this example were followed by other mining corporations whose acreage runs into the thousands while their operations are limited to a few square rods, it would greatly help to develop the possible gold resources of the South in the direction of new discoveries. We do not, however, wish to give the impression that larger and more valuable ore-deposits than those already exploited are still to be found; the more easily recognizable and richer outcrops have been worked over, and in any case such finds as may be made will probably present no new features.

In general, the abandoned mines present the same features as those that are working. Judging from some of the older reports (Silliman, Rogers, Emmons, etc.), the surface ores of these mines were very rich, due partially to local concentration near the surface from the eroded portions of the vein, and in other cases perhaps to pockets and shoots of limited extent and depth. In the earlier days, few of the veins were worked below the water-level; the abandonment of these older mines, cannot, however, always be laid to the appearance of refractory sulphurets. In the sulphuretted ores worked to-day from 20 to 60 per cent. of the gold is free, and in many of the earlier mines, where rich ores occurred in continuous shoots, these were followed down far below the water-level and the free gold which they contained was obtained by simple amalgamation, as for instance at the Gold Hill mine in North Carolina, where the workings extended to 740 feet in depth. The more plausible reasons for the abandonment of the so-called *rich* Southern gold

mines may be attributed to the pinching out of the ore-shoots outcropping at the surface or a diminution in the assay value of the ore. It is probable that the more expensive and difficult operations at such depths precluded the further search for other ore-bodies below the water-level. It must also be remembered that as early as 1840 at least partially successful attempts were made to work sulphurets.

In many of the mines, however, the ore-bodies were of low grade, though sometimes of large extent, and the small extraction of the free gold in the sulphuretted ores did not permit of a profitable continuation of the work. As in all mining regions, many other so-called plausible reasons are given for the abandonment of the mines, as, for instance, mismanagement, disputes among the owners, etc.

To determine the probable value of a mine an examination is of course absolutely necessary. A conclusive opinion is, however, in most cases impossible, even after the mine has been pumped out and examined, on account of the poor condition of the workings and the, at best, limited exposures of the ore-bodies. The prospective investor must, with few exceptions, bear the cost of the necessary exploratory development, which expenditure must be considered speculative. A great number of the properties are held at prohibitory figures, and arrangements for satisfactory examination under option or otherwise cannot be made, traditional merit and output being considered a sufficient proof of value by the owners.

In low-grade highly sulphuretted ore-bodies assays may give a fair indication of the value of the ore if the samples be fairly taken; but a test on a larger scale at one of the experimental chlorination plants,[1] in cases where it is intended to subsequently adopt the chlorination process, would be much more conclusive.

On higher grade, free-milling ores, however, assays, even if taken with care, will be of little value; the results will, in fact, often be misleading. In such cases a mill-test is imperative, and it can generally be made either in the mill at the mine itself, at some neighboring mill, or at test mills especially operated for this purpose.[2]

The most feasible propositions in the South appear to be the working of the larger low-grade ore-bodies. Rich veins as a rule have been in pockets and of small extent, more suited to the operations of tributors or small landowners, with the help, perhaps, of the wooden stamp-mill. It is a well-known fact that ore-deposits of this uncertain character cannot be worked systematically by larger companies with an extensive plant, and must be left to the individual miner, whose personal success pays his daily wages, and to whom an occasional strike is an inducement for continuous work.

[1] Captain A. Thies, Haile Mine, S. C., and Mecklenburg Iron Works, Charlotte, N. C.
[2] Mecklenburg Iron Works, N. C., and the Salisbury Supply Co., Salisbury, N. C.

Systematic work can only be pursued where the ore-bodies are large and continuous enough to warrant the establishment of a regular plant for mining, milling and reduction of the ores. The question of quantity means more than that of quality, so long as the former does not fall below a certain limit.

Among such may be classed the wide lenticular bodies of auriferous and pyritic slates, as at the Haile and Russell mines, and the persistent and continuous quartz-veins of sufficient width, such as at the Reimer and Capps mines. The more continuous and stronger ore-leads of the Dahlonega type may also be included here, such as at the Lockhart and the Franklin mines, which are at present being worked as deep mines, as well as those which have so far been worked by hydraulicking, like the Hand, Singleton, Findley, etc., mines.

In some localities smaller or irregular quartz-veins lying close together have been worked separately; it may prove feasible to mine these together as a body of low-grade ore, especially where the intervening and adjoining country-rock is to some degree auriferous, as at the Rocky River mine.

Such ores as are alluded to may be said to average between $3 and $7 per ton. There are exceptional cases of richer ore-bodies which have shown considerable continuity, as, for instance, at the Phœnix mine; but here, as is usual, the size of the vein and hence the quantity of the ore decreases proportionately with the improvement in the quality.

Almost without exception, a profitable extraction from Southern gold ores can only be attained by supplementing amalgamation with concentration of the sulphurets and by subsequent treatment of the latter. The practically universal adoption of the stamp-mill in the South verifies, as in other gold-mining regions, its more general applicability for crushing compared with other machinery. The two types of stamp-mills more especially characteristic of the South, each having its own field of action, have been described on pages 111 and 119. The milling practice varies greatly, as might be expected from the extremely variable character of the ores.

All of the Southern ores contain at least a portion of their gold in the free state, and excepting where other ingredients offer serious obstacles, or where a smelting process is intended, concentration is best preceded by amalgamation, so as to obtain the free gold as soon as possible and not endanger it to loss in subsequent treatment. Especially where the sulphurets are coarse and the crushing is not fine, a preliminary sizing in hydraulic classifiers and spitzkastens, and the treatment of each size on a separate vanning machine, is advisable. There has been a tendency to overcrowd these machines in the South; a saving of original cost here is but poor economy. It would seldom be advisable

to use less than two 4-foot belts to every five stamps. The degree of concentration (cleanness of the concentrates) must depend upon the ratio between the cost of subsequent treatment per ton, on the one hand, and a greater loss in tailings occasioned by close concentration on the other, the cost of concentration itself being practically the same in either extreme.

For the economical treatment of the concentrates chlorination by the Thies process furnishes in almost all cases a ready solution. The process is a simple one and is not patented; the cost of plant is comparatively small, and the percentage of extraction is high (94 to 97 per cent.). It has been in active operation on a continuous working scale at the two most successful mines in the South (Haile and Franklin mines). The presence of copper is objectionable in this process, as it increases the consumption of chemicals, and if in too large a quantity it may preclude the adoption of the process. At the Phœnix mine, N. C., ores running as high as 3 per cent. copper were, however, successfully treated. Ingredients which make dead-roasting difficult may also add to the cost of the process.

Sulphuret ores assaying only $3 per ton, when existing in extensive bodies, so as to permit operations on a larger scale, other conditions being favorable, might be worked at a profit by the application of this process.

Should concentration, on account of the too finely divided condition of the gold and sulphurets, prove impossible without a heavy loss in tailings, the cyanide, bromination or Swedish chlorination process might prove of value for a direct treatment of the ore; or the ore might be treated in bulk by the modification of the Thies process in use at Deadwood, Dakota; or by the Thies process proper on an enlarged scale, using, if necessary, closed filtering-tanks under pressure. In all of the above previous roasting is necessary, excepting perhaps in the cyanide process. Attempts with the latter have so far been unsuccessful. It will be of interest to watch the outcome of the plant at the Russell mine, N. C. Lack of success in the use of cyanide cannot always be laid to its lack of applicability; it certainly has, however, this disadvantage, that it requires a careful experimental trial, best made on a large scale and therefore expensive, as well as a continuous supervision afterwards by an experienced chemist, together with more or less skilled assistance, which is a requirement not always conformable with Southern conditions.

A small class of the Southern ores, referring particularly to those containing lead, copper and zinc, would have to be treated by smelting. A smelting plant would, however, only prove a financial success under the concerted action of all—or at least most—of the mines producing such

ores, a state of affairs which, under the present condition of gold mining in the South, seems difficult to attain. Several attempts have been made to gain this end, but have not been successful.

Taken as a whole, the gold ores of the Southern Appalachians present no greater difficulties of treatment than those of other fields, the distinguishing feature being perhaps their large variety, which makes a close study of each separate ore-body necessary.

As to the cost of labor in the South, it may be said that while it is low compared to that of the Western mining districts, and unskilled labor can be obtained at especially low cost, skilled labor commands about the same wages as throughout the East. It will be found here, as in other places, that the laborer is worthy of his hire. Some difficulty may be experienced in obtaining suitable labor, especially in those districts where no active mining work has been going on. In general there are no mining camps, in the Western sense of the word, and hence no regular mining population that might otherwise engender a more energetic mining spirit.

Among the facilities for operations in the South are the climate, which permits continuous working throughout the year; the accessibility of the mines to railroad lines, and their comparative proximity to investing Eastern capital. Lumber, timber and cord wood can be obtained at very low cost. Mining supplies and machinery are furnished from several central points in the field (Salisbury, Charlotte, Dahlonega, Atlanta). Water-power—in most cases, however, undeveloped—is abundant throughout a great portion of the mining belt. Should a revival in mining favor a development of properties in groups, central electric power distribution plants would be practicable in most districts.

Gold mining in the South has its favorable features, which should facilitate the economic working of the ore-deposits as legitimate business undertakings, with close and intelligent management. A considerable number of properties are at least worthy of investigation, and to the best of our belief, such investigations will disclose remunerative working opportunities, and will ultimately lead to a reasonable revival of gold mining in the South. Examinations would be greatly stimulated by more disinterested co-operation and reasonable demands of the mine owners, ultimately to their benefit. It is to be hoped that speculative investments in the Southern gold mines have had their day, and that all future operations will be conducted on such a business-like basis as begets confidence and stability.

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NORTH CAROLINA GEOLOGICAL SURVEY.

J. A. HOLMES, STATE GEOLOGIST.

BULLETIN No. 11.

CORUNDUM AND THE BASIC MAGNESIAN ROCKS OF WESTERN NORTH CAROLINA.

BY

JOSEPH VOLNEY LEWIS,

ASSISTANT GEOLOGIST.

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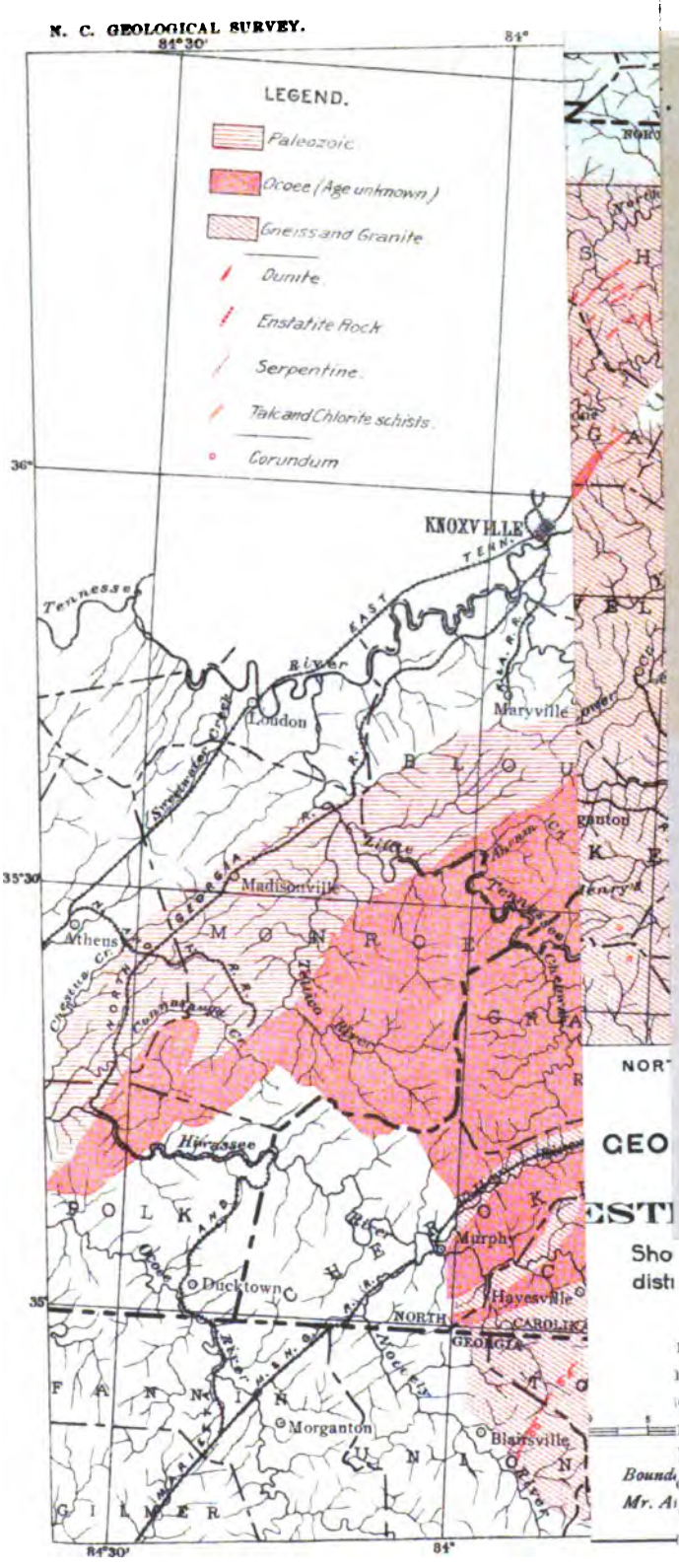

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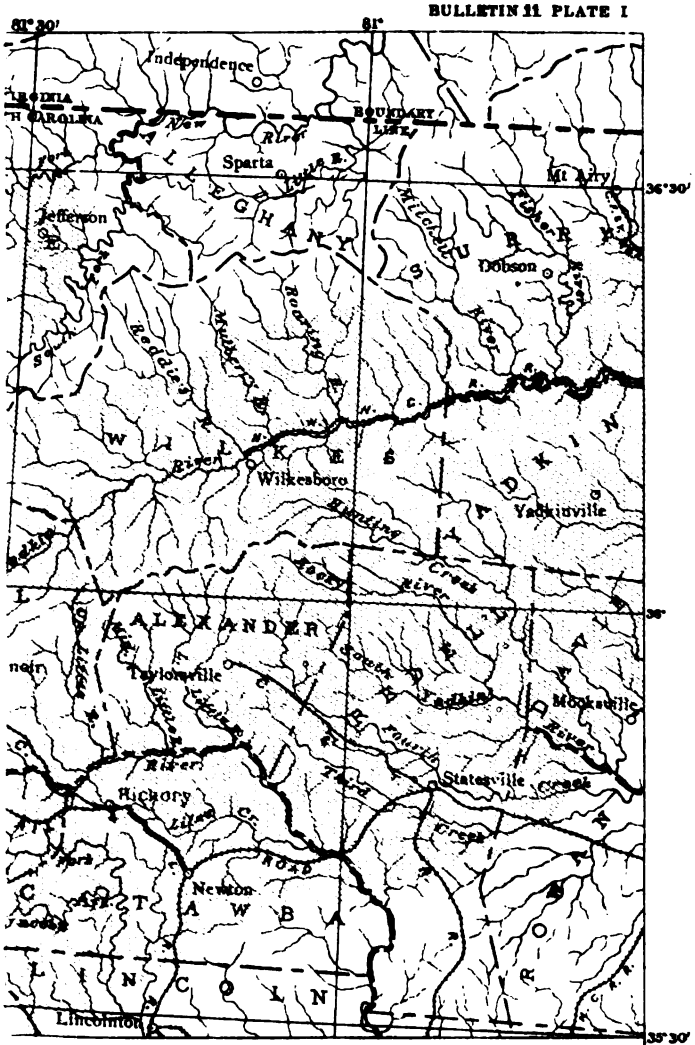

TH CAROLINA GEOLOGICAL SURVEY,
J.A. Holmes, State Geologist.

LOGIC SKETCH MAP
OF
ERN NORTH CAROLINA

wing Corundum Localities and the
-ibution of Peridotites and Related Rocks,

BY

J. Volney Lewis.

1895.

Scale.

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rthur Keith of the United States Geological Survey.

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NORTH CAROLINA GEOLOGICAL SURVEY.

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ASSISTANT GEOLOGIST.

MAP CORRECTIONS.

Through some misunderstanding several small errors have been made in the geological boundaries on the western portion of this map, chiefly in Unicoi, Cocke and Monroe counties, Tennessee, and in Madison and Mitchell counties in North Carolina. The errors were discovered too late to be corrected in this edition. Later work has also shown that the Ocoee rocks should be made to extend across the area left uncolored in Cherokee county (N. C.), and Polk county (Tenn.), and that the uncolored area in Wilkes, Alleghany and Ashe counties should be colored for "gneisses and granite." All needed corrections will be made in a future edition of this map, which it is expected will be published at an early date.

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LETTER OF TRANSMITTAL.

RALEIGH, N. C., December 1st, 1895.

To His Excellency HON. ELIAS CARR,

Governor of North Carolina.

SIR:—I beg to submit for publication as Bulletin 11 of the Geological Survey, a preliminary report on Corundum and the associated basic Magnesian Rocks in North Carolina, by Mr. J. V. Lewis. The larger part of the corundum now produced in the United States is mined in North Carolina, and the increasing demand for information on this subject has led to the preparation of this paper. It is hoped that a more elaborate final report on the subject can be prepared by the close of another year.

With great respect, I have the honor to be, sir,

Yours obediently,

J. A. HOLMES,

State Geologist.

CORUNDUM AND THE BASIC MAGNESIAN ROCKS IN WESTERN NORTH CAROLINA.

BY

J. VOLNEY LEWIS.

CORUNDUM AND THE BASIC MAGNESIAN ROCKS IN WESTERN NORTH CAROLINA.

By J. Volney Lewis.

I. INTRODUCTION.

The present incomplete report is issued for the purpose of presenting the field results obtained chiefly during the summer months of 1893 and 1894.

To the fact that it is mainly a report of field observations is due, to a great extent, its incompleteness; and I would urge this consideration as an apology for certain vagaries of mineralogic terminology in the following pages, and for many unsatisfactory points in geologic and petrographic descriptions. As far as possible, I have confined myself to a simple presentation of facts thus far determined, and the more theoretical discussions have been avoided.

In the beginning of the field season of 1893, a rapid reconnaissance of the region under consideration was made with the late Dr. George H. Williams, of Johns Hopkins University; and a portion of the laboratory work and the field studies for both this and the succeeding seasons were prosecuted, to a great extent, under his guidance and general supervision. Specimens were collected from all portions of the region, and by the courtesy and cooperation of the Director of the United States Geological Survey, I have begun the microscopic study of this material in the Survey laboratories, at Washington. A more thorough report on the corundum-bearing rocks, embodying the results of this work, will be published as soon as practicable.

One acquainted with the methods and aims of geology, or of any natural science, needs no argument to point out the necessity of

thorough detailed work for the understanding of any problem in Nature, whether of immediate economic importance or only of scientific interest. Thus far all that is known of the extent and value of our corundum deposits has been derived from experience; that is to say, from actual prospecting and mining. Studies of considerable interest and value in the corundum regions have been made by Chatard, Julien, Shepard, Genth and others, but these have been confined chiefly to local occurrences and special problems, and no attempt has been made to cover the whole field; consequently, the various theories that have been advanced in regard to the origin of corundum and its associated rocks have left entirely out of consideration much evidence which only a careful survey of the whole area could furnish.

I can scarcely hope, by the work in hand, to furnish a final or even a very satisfactory answer to the question of origin; for such problems, in areas of great disturbance and so thoroughly metamorphosed as the one under consideration, do not readily yield clear results; but it is hoped that even the facts recorded here may add something to the small sum of our knowledge of these interesting formations, and that thereby a somewhat clearer understanding of their geologic relations may be attained.

From the standpoint of the prospector, miner, or land-owner, whose interest in such matters is eminently practical and whose geologic training is entirely the result of work and observations in the mines themselves, it is hoped that this presentation of facts may be found useful, and that the mining interests of every section may be advanced by a study of conditions existing in other portions of the field. In fact, this method of comparison has been found the only practical guide in the search for new localities or in the development of deposits already known. If the rocks and associated minerals of a given locality are the same as found in a corundum mine, the prospector goes to work on the hypothesis that the occurrence there of corundum itself is entirely probable. While characteristic differences are everywhere observed between mines, even in the same immediate neighborhood, yet experience has shown that the conditions for the occurrence of corundum are practically the same throughout the region. The few important

exceptions to this rule are noted further on in describing the modes of occurrence.

For the reasons suggested, then, it has been thought advisable to publish the facts gathered in the field, along with some general observations on the geology of the region and the characteristics of the corundum-bearing rocks, rather than hold these for the appearance of the final report. A knowledge of the facts cannot but advance the interests of legitimate mining, as well as prevent such waste of time and money as may sometimes be observed in western North Carolina.

At the present writing, the only active corundum mining in the world is in this State, and, with the important exception of Georgia, North Carolina has supplied the only corundum on the market since the beginning of the industry more than twenty years ago. Besides regular mining, much work has been done in exploring and prospecting, and considerable investments have recently been made with a view to engaging in active mining at an early date. Explorations have never been more actively prosecuted and it is not unlikely that production will be largely increased in the near future by the opening of new mines. That there is abundant demand for such increase is shown by the fact that, in addition to the available corundum, there are annually imported for consumption in the United States from 3,000 to 5,000 tons of emery, which is practically the only mineral product that competes with corundum in the market.

The combination of circumstances favorable to mining and milling operations in North Carolina—the equable climate and the almost universal presence of water-power—together with the great superiority of corundum as an abrasive, combine to place these formations among the important resources of the State.

2. GEOLOGIC SKETCH OF THE CORUNDUM REGION.

From the accompanying map it will be seen that what we may term the *Corundum belt* in North Carolina is confined to a broad strip of gneisses lying chiefly west of the Blue Ridge and extending northwestward from the Georgia boundary through Clay,

Macon, Transylvania, Jackson, Haywood, Buncombe, Madison, and Yancey counties, while the peridotites with their characteristic chromium- and nickel-bearing minerals, asbestos, etc., extend the belt through Mitchell, Watauga, Ashe, and Alleghany counties to the Virginia line.

This belt is but a portion of the greater belt of crystalline rocks which is coextensive with the Appalachian mountain system (see plate II), and which, on account of its complex and highly crystalline character, is generally considered to be of Archean age. The southern extremity of this belt disappears under the younger formations in central Alabama. Its principal constituent is gneiss, often, through higher development of lamination, passing into schists, and including frequent masses of granitic and other distinctively igneous rocks.

These gneisses have been usually considered to be, in great part, sedimentary rocks that have lost their original clastic characteristics, with the possible exception in some cases of bedding, in the great earth-movements and other metamorphosing agencies in which they have been involved. Some of them, however, are certainly granites or other massive rocks that have been sheared or squeezed by the same agencies—transitions from the massive to the laminated forms being often easily observed and, in fact, almost universally present about the borders of the massive rocks of the region.

When these changes have affected the whole of such an igneous mass, it is obvious that a rock will result that will often be difficult and sometimes impossible to distinguish, in the field, from a metamorphosed sediment of similar composition. As yet the geology of this area is not sufficiently known to map these varieties separately; though such distinctions are highly desirable in considering the questions of origin of some of the massive rocks and their relations to the prevalent structural types of the region.

By the earlier geologists, the lamination of the gneiss was considered true bedding, and their attempts to interpret the structure of the region were based on this misconception. It is well known that lamination is often developed where no such original structure existed, as in the sheared massive rocks alluded to above. It

is also known that such structure produced by movement in the mass of the rock may, and usually does, obliterate whatever original structure may have been present; so that a sedimentary rock thus mechanically laminated and at the same time thoroughly crystallized would no longer show its original stratification. The new structural planes might correspond in certain cases with bedding, but often they would not; and hence the strikes and dips observed in this region and recorded here, being those of lamination planes, are not in any case to be interpreted as true strikes and dips.

The prevailing strike of the lamination planes in the gneiss of western North Carolina is about north 30° east, and the prevailing dip is at a high angle toward the southeast. Very frequently local variations occur, especially in the dips, and often the prevalent southeasterly dip will become vertical and, tipping over, will pass into a northwesterly dip within an outcrop of only a few feet. All stages occur from these local variations in dip and strike to the most gnarled and contorted forms imaginable. In general, the lamination has suffered the most deformation in the immediate vicinity of igneous intrusions; or perhaps the statement might be reversed, as the forces that produced the contortions doubtless formed simultaneously the fissures into which the massive rocks were injected.

Constituting a small proportion of this belt, as regards area, are the basic magnesian rocks, chiefly peridotites, which are here specially considered in their relations to the occurrence of corundum. These occur in small lenticular masses or in narrow strips, rarely exceeding a mile or two in length, and, so far as I am aware, are nowhere intimately associated with the well recognized igneous rocks of the granitic type. Contortions are observed, however, in the adjacent gneisses similar to those in the vicinity of granites, and often a transition to mica-schist gives evidence of an unusual amount of movement.

The magnesian rocks, too, whether peridotites or pyroxenites, have always a sheath of schistose talc developed about their borders and, in the corundum-bearing region, also much chlorite. Hence there is never, as far as observed, an absolute contact between these massive rocks and normal gneiss.

South of Virginia, the gneissic belt is flanked on the west by a broad strip of partially metamorphosed but generally distinct sediments of undetermined geologic age. No fossils have yet been found in them and structures are greatly confused by disturbances that have given rise to the Appalachian system of mountains. Hence their relations to the known Paleozoic rocks, by which, in turn, they are bordered on the west, is, as yet, a matter of controversy. These beds consist of a lower series of shales and limestones lying uncomformably on the gneisses, and followed by conglomerates and sandstones above. To the whole formation the name *Ocoee* has been given.

Referring again to the map (plate I.), it will be seen that two belts of Ocoee are developed in western North Carolina; the one, lying along the Tennessee border, a broad area of irregular outline and tapering northward to a point just south of Johnson City, Tennessee. Beyond this point, as far as the boundary has been traced northward, the paleozoic formations lie directly in contact with the gneisses. The other Ocoee belt forms a narrow strip lying about forty miles further east in its southern portion, and passing northwestward from the upper French Broad valley, approximately in the direction of the Blue Ridge. The irregular boundary of the western area brings the two belts within twenty-five miles of each other in places, but the general trend of them both is the same as that of all the rocks of the region, and corresponds to the axes of Appalachian folding.

The eastern belt is exceedingly narrow in its southern portion, perhaps even narrower in places than indicated on the map, but it broadens northward and becomes involved in extremely complex folds and faults in Mitchell and Watauga counties. It should be stated that, north of the 36th parallel, as the detail on the map would indicate, the boundaries of this belt are much more accurately determined than in its southern extension. East of this narrow strip of Ocoee, comes a broad expanse of gneisses and granites, extending beyond Charlotte, Salisbury, and Greensboro, and forming the Piedmont plateau region of the State.

The corundum-bearing peridotite belt lies wholly within the strip of gneiss between these two belts of Ocoee. Almost the

whole width of this strip in the southwestern portion of the State is thickly dotted with small peridotite areas, but north of Waynesville they become more irregular and scattering. The manner of distribution is shown on the map, but, for the sake of clearness, the areal proportions are there often necessarily exaggerated. This is especially true of the schistose talc and chlorite rocks, which seldom exceed twenty or thirty feet in width of outcrop.

3. THE PERIDOTITES AND ASSOCIATED MASSIVE ROCKS.

As the corundum deposits of the State are found chiefly in connection with these rocks, it is important, before passing to the consideration of these deposits, to give brief descriptions of the peridotites and related rocks, in order that the descriptions of mines that follow may be more fully understood.

The rocks to be considered may be classed in three groups, namely : *peridotites*, *pyroxenites*, *amphibolites*. Of these, the first group largely predominates, and the others are regarded as only variant or accompanying forms of the same geologic unit. They sometimes, however, attain considerable importance as independent rock masses.

(1.) THE PERIDOTITES.

The peridotites appear in numerous small oval or lenticular masses of dimensions rarely exceeding a few hundred feet. Sometimes these lenses merge into each other and form a narrow strip a mile or two in length with constrictions at intervals, thus resembling, in form, a string of sausages. In rare cases, the outcrops present an irregular boundary, and cover areas of several hundred acres. The Buck creek area in Clay county, and that at Webster in Jackson county, are the largest masses of the belt, and their form and extent are shown approximately on the small scale map, plate I. (See also plates III and V.)

These rocks are in general perfectly massive and structureless, though a parallel structure is often developed about the borders; and at Webster the whole mass is so perfectly laminated as to pre-

sent a striking resemblance to a thin-bedded sandstone. As stated, however, this structure is exceptional, even the small bodies and narrow strips preserving a perfectly massive character.

This is often true, even where there has been considerable movement along the contacts between the gneiss and peridotites, resulting in the frequent development of mica-schist in the adjoining gneisses and the universal presence of schistose talc in the borders of the dunite. The boundaries have thus become veritable slickensides, and hence no true contacts between the peridotites and gneisses have been observed, and original contact metamorphism, if such ever existed here, has been entirely obliterated.

The peridotites of North Carolina represent a petrographic unit; and no extensive field work is necessary to convince one that any attempt to subdivide them must proceed on comparatively slight mineralogical differences, and the classes established regarded as mere varieties. Thin sections cut from different portions of the same outcrop might be made the basis for the establishment of three or four petrographic divisions; but, in the field, the lines of separation cannot be sharply drawn. The classes made in the laboratory are found to merge into each other, forming parts of the same rock mass.

However, with a clear understanding of this unity, the established classification of the peridotites may be useful for purely petrographic purposes; and, in deference to usage, the more prominent types observed in the State are here considered separately. These are *dunite*, the pure olivine rock; *harzburgite* (saxonite), that composed of olivine and orthorhombic pyroxene; *amphibole-picrite*, consisting essentially of olivine and hornblende; *forellenstein* (troctolite), the olivine-feldspar rock, which is not a peridotite according to the definition of that class; namely, that it consists of olivine rocks without essential feldspar. Forellenstein is usually regarded as a phase of olivine-gabbro produced by the suppression of the pyroxene—indeed, it may be questioned whether most peridotites should not also be so considered—but on the ground of geologic unity, it is here classed with the peridotites.

a. DUNITE.

The type of this rock was discovered in Dun mountain, New Zealand, about thirty years ago, and described by von Hochstetter as a light yellowish-green to grayish-green, crystalline granular rock, with an oily to a glassy lustre, and an uneven angular fracture. The dull, rust-brown color of the barren, weathered surface gave the mountain its name and, indirectly, the rock itself. It was found to consist almost exclusively of granular olivine, with chromite or picotite, in octahedral crystals the size of a pin-head, scattered through the mass.

The North Carolina dunite is very close to this type. It is usually composed of quite small grains of olivine, about the size of granulated sugar, though sometimes much coarser rock is found in small quantities, and large grains are often scattered through the fine-grained masses.

Small octahedrons or rounded grains of chromite or picotite are sparsely scattered through nearly all the olivine rocks. Sometimes these become very plentiful, and are then frequently segregated into vein-like streaks or pockets, and attain importance as a chromium ore. Long, glistening needles of tremolite are often observed, and sometimes flakes of talc and chlorite.

The colors include nearly all shades from light brownish yellow to a dark green, though the freshest specimens seem to be those of light oil-green or yellowish green color. Brown and yellow tints are generally more superficial and seem to be the results of oxidation of the iron constituent in the incipient stages of decomposition; and a dark green color may sometimes be seen, by the aid of a lens, to be the result of a partial alteration to serpentine. The dark green, fine grained varieties are usually tough, and the coarser grained, yellowish ones are very friable, being often easily crumbled with the fingers, even when apparently quite fresh. The more thinly laminated varieties about Webster and elsewhere are usually partly altered and quite friable also.

The characteristic dull brown color of the weathered surface is the same here as described for the New Zealand rock. By decomposition, an ochreous soil is produced which, on account of its

infertility and the consequent absence of vegetation, is easily removed by rains; and hence the outcrops are nearly always made conspicuous by barren areas of brown, angular rocks in a region otherwise well wooded.

Under the microscope, in ordinary light, dunite is seen to consist of irregular, angular grains of translucent, colorless olivine. In the fresh specimens, the angles of these grains fit accurately into each other with no interstitial matter whatever (Plate VI, figure 1); though in the great majority of cases there has been a slight alteration along the cracks into serpentine, and this secondary material surrounds every grain completely like mortar in a rubble wall. (Plate VI, figure 2.)

The microscope also reveals the fact that many of these rocks now of fine texture have resulted from cracking up the grains of a much coarser rock. In this process the remnants of these originally large grains have suffered very little or no displacement, for in polarized light they still extinguish together over considerable areas. (Plate VI, figure 3.) In some cases, however, these fractured grains have also been slightly sheared, and, hence, of course, the small fragments have rolled somewhat on each other and the evidence of its having once been a coarse grained rock is more or less completely obliterated. Sometimes, too, these grains show the development of a distinct cleavage parallel to the brachypinacoidal plane of the crystal; and more rarely, a basal cleavage is developed at right angles to this.

Besides olivine, either chromite or picotite, while neither is an essential constituent of dunite, is always present in rounded grains, occasionally in crystals, scattered through the rock; and hence they must be regarded as characteristic accessories. The distinction between these two minerals under the microscope, if indeed a sharp line may be drawn between them at all, is often quite difficult to make. No chemical or other special investigations have yet been made in connection with this work, and the two names are used rather loosely in the descriptions of microscopic characters of the rock. A review of a considerable amount of literature on similar studies shows quite a prevalent indefiniteness in referring to these minerals, and emphasizes the need of more

thorough chemical and microscopic investigation for the purpose of establishing definitely the relations between them.

In the study of these North Carolina rocks, I have called the opaque mineral that shows a dull grayish color by reflected light *chromite;* and for all those varieties that are translucent and of a yellowish or reddish brown color I have used the name *picotite.* The thoroughly unsatisfactory nature of this classification is more readily understood when it is found that every possible gradation between the bright yellowish brown, translucent mineral and the dull, opaque one are found in the same rock, and, indeed, may often be seen in the same thin section. The most natural explanation of these facts seems to lie in the hypothesis that we have here a complete chemical series, as pointed out by Wadsworth*; and further work on the chemical relations of these minerals, to be of the greatest value, should also take into account their microscopic characters.

In some of the olivine-feldspar rocks described below, the relations are even more striking than this; for quite frequently the clear, translucent picotite is surrounded by a border of opaque mineral with a sharp line between them, and the width of this border varies from a thin peripheral line to a band so broad that there appears only a minute grain of translucent mineral in the middle.

The size of the grains of chromite, or picotite, as the case may be, usually does not vary very widely from that of the olivine grains, though sometimes they are conspicuously larger. This is usually true where the quantity present is largely in excess of the normal, so that prominent segregations of it appear, sometimes attaining the importance of an ore, as mentioned above. Masses of such ore have been found in the vicinity of Webster, in Jackson county; near Burnsville, in Yancey county; northwest of Boone, in Watauga county, etc.

Other accessory constituents of dunite which are seen under the microscope, and which sometimes become prominent macroscopically, may be briefly mentioned. Enstatite in irregular grains is quite often seen, and is sometimes pleochroic. Less often, diallage is found. A light green hornblende, in elongated prisms, and giving

*Lithological Studies, Cambridge, 1884, pp. 176-186.

under the microscope properties of actinolite, is often found in the rock at Buck creek, Clay county, and sometimes on Shooting creek.

The minerals described above are the only ones that have been at all commonly observed in the perfectly fresh dunite. As soon as alteration begins, there appear a considerable number of new minerals among the secondary products; and, as has been already mentioned, at least some alteration may be seen in most of the sections when examined microscopically.

By far the most prevalent product of alteration, and one that is to a certain extent well-nigh universal, is serpentine. The first stage in serpentinization of the olivine is seen in the narrow line of yellowish or greenish, low-refracting substance that appears along the borders of the grains, forming a fine network, which completely envelops the olivine. Later, it forms along the irregular fissures and cleavage cracks through the individual grains themselves; and gradually, as these are altered more and more along their borders, the serpentine replaces the olivine till no trace of the original mineral is left.

In the earlier stages, this alteration is very common, almost universal, in the dunite; but, in North Carolina, complete alteration, save in a few small areas, is exceptional. The process is seldom carried so far as to destroy the granular, sandy nature of the rock over any considerable area. Plate VI (figures 1, 2, 4, and 5,) shows successive stages in this process, together with some of the characteristic phenomena that attend it. A deposition of magnetite in fine grains in the beginning of the alteration is very common, and a net-work of black lines is thus formed that often outlines the original olivine grains after the whole has passed into massive serpentine. Sometimes the rejected ferruginous materials take the form of a lower oxid and stain the serpentine and also the olivine remnants a deep yellowish brown. Where cleavages are developed in the olivine, the alteration to serpentine usually takes place more readily along that parallel to the basal plane, though the brachypinacoidal cleavage is always more highly developed.

The same difference in resistance to chemical action along these two planes is observed in the development of chlorite in the olivine.

Chlorite is often present in the partially serpentinized specimens and also in many cases where there is no serpentine. The hornblende-bearing variety (amphibole-picrite) generally shows more or less alteration of the hornblende to chlorite, and sometimes only scattered remnants of it are left entirely surrounded by the secondary product.

But chlorite is often distinctly the result of alteration of the olivine also, as seen in its frequent development along cracks and cleavage planes; and still more conclusively in those cases where the chlorite penetrates the solid olivine grains and gradually replaces them, much in the same manner as serpentine. In such alteration there is, of course, an accession of alumina from some source outside of the olivine itself, this mineral being simply a combination of the silicates of iron and magnesium in varying proportions and entirely free from alumina. The same is true of the production of talc, which is much less frequent in these rocks. With the formation of chlorite there also occurs a segregation of the fine grains of magnetite into irregular patches or large grains, and these are frequently given a skeleton appearance by the laths or chlorite that penetrate them. Such masses of magnetite are almost universally surrounded by a zone of chlorite or a mixture of chlorite and talc, in radiating fibres approximately at right angles to their boundaries.

Tremolite, in long slender needles, is often present with serpentine and chlorite, and is sometimes largely developed where very little of the other two has be· enformed. Its secondary nature is unmistakable, in most cases, from the manner in which it penetrates the olivine grains in every direction, often passing through several in succession without reference to the orientation of cleavages or crystallographic axes. The tremolite, in turn, is frequently more or less altered to talc and chlorite; and most of the specimens showing talc also bear some tremolite, so that such alteration may often, though not always, account for the presence of talc in dunite. In some cases it is evidently the result of alteration of enstatite, as shown by remnants of the original mineral and by the form which the talc still retains.

Enstatite, in some cases at least, is a secondary product, as often

seen in the radial casing which it forms along the joint-planes of the dunite. This is especially prominent at the north end of Corundum Hill, and is more or less developed in a great many of the outcrops throughout the State.

The casing varies from an inch or less in thickness to 12 or 14 inches, and generally contains more or less chlorite in scattering scales through it. It is always fibrous in structure, with the fibres arranged approximately normal to the surface of the enclosed dunite; and may sometimes be separated into two or more consecutive layers, practically identical in structure and composition. The outer portions of these casings are often altered to talc, and sometimes this has been rendered schistose by subsequent shearing so as to wrap these portions round the boulders in thin laminæ. Such layers are seen to be continuous with the unaltered portions of the casing which still stand perpendicular to the surface of the enclosed block of dunite.

Casings of this nature are often broken through in mining for corundum, and the enclosed block found to be completely altered to a yellow ochreous earth that easily crumbles on exposure. The connection of this enstatite with the corundum veins will be discussed later in describing the modes of occurrence of corundum.

Carbonates in small quantities, sometimes forming little veins through the rock, are found in the specimens that have suffered considerable alteration. They are readily recognized under the microscope by their high double refraction and well-developed rhombohedral cleavage. No tests were made of their chemical nature, but they are doubtless ordinary magnesium carbonate, or magnesite.

In the final weathering and disintegration of dunite, silica, in the form of chalcedony, is deposited in irregular masses in the joints and cracks; and garnierite, genthite, and other nickel-bearing silicates are formed in cases where the olivine carries small quantities of nickel. These minerals, however, never form important rock masses, though the nickel minerals have been found in sufficient quantity in some localities to attract attention from a commercial standpoint.

The original minerals and alteration products described above

are found in practically all the dunite localities of the State; in fact, there is remarkably little variation in the characters of the rock throughout the region, much less than in the corundum and its associated minerals. Such variations as do exist are chiefly in the relative proportions of the various minerals resulting from alternation rather than in the original constitution of the rock, and important characters of this nature will be pointed out below in enumerating the peridotite localities.

b. HARZBURGITE (Saxonite).

This is essentially an olivine-enstatite rock and is found in this region chiefly as a transition between the dunite and the enstatite rock described below, though there are a few exceptions and these are of sufficient extent and importance to warrant a separate consideration. The two principal constituents occur in very variable proportions, and, besides these, all the accessory minerals of dunite are also present. The olivine, chromite, etc., are identical with the same minerals as found in dunite, and the enstatite has the same essential characteristics. But here it is much more highly developed and becomes an essential constituent, being always present in macroscopic dimensions, and prominent for its glistening cleavage faces.

The alteration processes are the same as for dunite. The enstatite alters in some cases to serpentine, just as described for olivine, but oftener it changes to talc. This is especially true of the enstatite in the pyroxenites described below. Harzburgite is found principally in large outcrops near Bakersville, Mitchell county, and near Elk Cross Roads, Ashe county; Balsam Gap, Jackson county; and Mine creek, Yancey county.

c. AMPHIBOLE-PICRITE.

This rock is very similar in structure to the harzburgite described above, an amphibole (hornblende) mineral, resembling actinolite, replacing the enstatite as an essential constituent. Enstatite is frequently present, however, and the grains and crystals of chromite or picotite constitute characteristic accessories, as in dunite. The

hornblende is often partially or wholly altered to chlorite, and it is very probable that the chlorite of the olivine rocks of this region may have originated often in this manner. A considerable portion of the Buck creek peridotite mass, especially towards the north end of the mountain, is composed of rock which conforms closely to this type.

d. FORELLENSTEIN (Troctolite).

This rock type, composed essentially of olivine and feldspar, has been found in important development at only one locality; namely, on the eastern border of the dunite area at Buck creek, in Clay county. It is also found in small amounts on Shooting creek, where the rock associations are similiar in many ways to those of Buck creek. The whole outcrop at the former place covers an area of only about two acres, but it is interesting on account of its connection with the dunite, instead of with gabbro, as usually found, and also on account of the rarity of this type of rock. So for as I am aware, this is the first recorded instance of forellenstein as a phase of peridotite.

The rock is composed almost entirely of olivine and a basic feldspar (anorthite), and the zones of intermediate silicates developed along the borders between these minerals.

A small amount of feldspar that was separated by heavy solution for analysis showed some kaolinization when examined with the microscope, but the following partial analysis places it unmistakably with anorthite.

Partial Analysis of Feldspar (Anorthite) from Forellenstein of Buck Creek, Clay County, N. C.

	Percentage Determined.	On basis of 100 per cent.
Silica	40.40	42.29
Alumina	18.72	19.60
Lime	36.40	38.11
	95.52	100.00

The percentages, calculated on a basis of 100, are only approximately correct for the pure mineral, as magnesia probably exists in combination with part of the silica. The quantity available was too small to give more than approximate results.

In this rock, the olivine nowhere borders directly on the feldspar, but it is separated from it by a double zone of fibrous minerals, arranged at right angles to the boundaries. Rarely, one portion is absent and the minerals are separated only by a single zone. Such reaction rims have been described often from olivine gabbros, and their optical properties were carefully studied by Dr. F. D. Adams, in an occurrence in the anorthosites of Canada, which is exactly similar to this North Carolina rock, except that the reaction rims of the latter are somewhat more highly developed than in any occurrence heretofore described.

Dr. Adams found that the portion of this zone adjacent to the olivine corresponded in optical properties with enstatite, and that the other part is made up of a fibrous green hornblende. In the North Carolina rock, this latter is sometimes perfectly continuous with large cleavable masses of hornblende, and its identity is thus easily recognized microscopically. But the other portion cannot be satisfactorily determined without separation of the minerals from the powdered rock, and this I hope to do before the publication of the final report on these rocks.

(2.) PYROXENITES.

Two types of this family are found in closest connection with the peridotites, and sometimes passing gradually into them, though usually much more sharply differentiated than the different varieties of the peridotite from each other. Two very distinct types of pyroxenite have been observed, namely, that composed of orthorhombic pyroxene, *enstatite rock*; and, one consisting of both monoclinic and orthorhombic pyroxenes, *websterite*.

a. ENSTATITE ROCK.

This rock, as its name indicates, is composed chiefly of the orthorhombic pyroxene, which is usually in large bladed, interlocking

crystals of a grayish or yellowish color. In some places where it is considerably developed it forms a mass perfectly continuous with the dunite, as at Corundum Hill, Macon county, and in some of the outcrops of the Sapphire mine in Jackson county. At other Sapphire localities, and especially in Transylvania and Watauga counties, it forms separate rock masses of considerable extent. Besides occasional grains of olivine and chromite, this rock scarcely contains anything else than enstatite and its alteration products.

The alteration consists entirely, so far as observed in this region, of a change into talc. Even the freshest looking specimens often have greenish, transparent talc developed in them, and frequently large masses that have undergone this alteration still retain perfectly the form and appearance of the original mineral. This is often true also of talc in enstatite-bearing peridotite (harzburgite), as may be seen in that near Balsam gap, in Jackson county.

Dr. C. D. Smith considered the chief constituent of this rock to be anthophyllite,* and the same term has been employed by some later writers. Rocks of a similar character at the Pine Mountain mine, Rabun county, Georgia, are also called anthophyllite by Mr. Francis P. King.*

In view of this usage and the extreme scarcity of well determined localities for true orthorhombic amphibole, I had a specimen of the mineral from Corundum Hill analyzed in the laboratory of the Survey by Dr. Charles Baskerville, with the result given below in column I. Talc could be seen in small amounts in the specimen from which the sample was taken. This was carefully excluded from the material analyzed, but the high percentage of water shows that considerable alteration had taken place. There can be no doubt, however, of the true character of the mineral. Deducting the water and calculating the percentage on the basis of 100, we obtain the results given in column II., and these figures represent a normal enstatite with a high iron constituent, and near the bronzite variety.

*Report Geol. Sur. N. C. I., 1875, appendix, page 93.
*Bulletin 2, Geol. Sur. of Georgia, 1894, pages 79, 82, etc.

An analysis of another specimen from the same locality by Mr. Frank Julian* is given in column III, for comparison.

Analyses of enstatite from Corundum Hill, Macon county:

	I.	II.	III.
Silica	51.64	54.95	57.30
Alumina	0.12	.....	trace
Ferrous oxid	9.28	9.87	7.45
Lime	0.45	.....	.....
Magnesia	31.93	33.97	34.64
Manganese oxid	0.56	.....	.....
Water	5.45	.....	1.21
	99.43	.....	100.60

No other specimens have been determined, and the name is applied to rocks of other localities on general resemblance. It is possible that some of them may prove to be of a different nature.

b. WEBSTERITE.

This rock was first described and named by the late Dr. G. H. Williams from specimens collected at Webster, Jackson county.* Thus far, besides the type locality near the town of Webster, it has been observed only in the continuation of the same outcrop of dunite on Cane creek, about six miles further east. It is composed of both orthorhombic and monoclinic pyroxenes in a compact, granular mass, closely resembling the dunite with which it is associated, and forming a part of the same rock mass. So far as observed, however, there is no gradual transition from one to the other, the two types remaining quite distinct.

The Webster dunite, as before stated, is very highly laminated, and in the midst of this rock, which appears on a hillside facing the Tuckaseegee river in an outcrop over 1,500 feet wide, the websterite occupies a width of about 300 feet. It may be traced for about a mile in length, in this type locality; then it thins out and does not appear again, except in the Cane creek outcrop mentioned

*Bulletin 74, U. S. Geol. Sur., Minerals of North Carolina, 1891, page 43.
*American Geologist, VI, 1890, pages 41-44.

above. It is more massive in character than the dunite, has a more brilliant green color, and is less altered on the surface. It is also quite prominent in the field, owing to the vigorous vegetation which it supports, in contrast with the barren dunite.

(3.) AMPHIBOLITE.

This term is here used to indicate massive rocks composed wholly or chiefly of amphiboles. The most important to be considered here is the beautiful green, feldspathic, hornblende rock, which often bears pink and red corundum in the Shooting creek and Buck creek localities of Clay county. It is principally composed of grass-green hornblende and the lime-feldspar, anorthite, in greatly varying proportions; and its structure is usually laminated and gneissic, though massive forms are not entirely wanting. The corundum which it bears occurs in masses from the minutest microscopic grains to broad cleavable plates three or four inches in diameter.

The rock is very fine-grained and exceedingly tough; and, hence, it has not been found practicable to crush it for the separation of the corundum. Transitions from this type to the dunite, with which it occurs, are found on top of the mountain west of the mine, at Buck creek. The intermediate stages have about the same composition and structure as the forellenstein described above; but they never assume sufficient importance in this connection to be classed as a separate rock. The relations of this rock to the dunite (see map, plate III) is strongly suggestive of a system of dikes cutting the latter. On Shooting creek, Clay county, it usually occurs in narrow strips beside the dunite, though sometimes in masses of equal size.

The hornblende of this rock has usually been referred to the species *smaragdite*,* but analyses show it to be an aluminous hornblende, and the late Professor Dana classed it with *edenite*. The brilliant color is undoubtedly due to the chromium present. This is more plainly seen when the powder of the rock is examined under the

*F. A. Genth, Bulletin 74, U. S. Geological Survey, 1891, 45. F. P. King, Bulletin 2, Geol. Survey of Georgia, 1894, 44, 45.

microscope. When the mineral is separated from this powder with heavy solutions, the heavier fragments are all seen to contain inclusions of picotite in minute grains, and to be of a much brighter green immediately around these inclusions. This will account for some of the chromic oxid found in analyses. The purer mineral thus separated was analyzed by Dr. Charles Baskerville, with the results given in column I. That in column II is an analysis of the same mineral (without separating the grains with picotite) given by Dr. Genth in the bulletin referred to above.

Analyses of Alumiuous hornblende from Buck creek, Clay county:

	I.	II.
Silica	44.38	45.14
Alumina	17.32	17.59
Chromic oxid	0.38	0.79
Ferrous oxid	3.83	3.45
Nickelous oxid	.....	0.21
Magnesia	15.48	16.69
Manganese oxid	0.90	.....
Lime	11.51	12.51
Soda	1.24	2.25
Potash	0.38	0.36
Water	4.63	1.34
	100.03	100.33
Specific gravity	3.075	3.120

The specific gravity given by Dr. Genth was determined on the grass-green variety, and it is natural to suppose that picotite inclusions cause the greater weight as well as the higher chrome percentage. Feldspar was separated and found to agree both in specific gravity and extinction angles with typical anorthite.

4. ASSOCIATED SECONDARY AND SCHISTOSE ROCKS.

Besides the schistose phases of the massive rocks described above, there are found frequent large masses of talc- and chlorite-schists in connection with the typical dunite, as well as with the other associated rocks. Serpentine is extensively developed in only one portion of the region, and is evidently an altered dunite.

(1.) MASSIVE ROCKS.

a. SERPENTINE.

Massive serpentine is almost the universal result of exposure of olivine rocks to hydration process. These rocks in North Carolina have been subjected to this alteration in but few places. Throughout the greater portion of the belt, the outcrops of the peridotites are almost perfectly fresh to the very surface of the exposure; and such alteration as has taken place is usually in the nature of a direct decomposition of the olivine, forming magnesium carbonate, which is mostly carried away in solution, and a residue of limonite and silica, the latter remaining as chalcedony. As stated in the description of dunite, however, most of the sections of this rock show, under the microscope, some slight alteration to serpentine along the cracks; and it seems quite probable that this is the first stage in the decomposition and disintegration of the rock through ordinary weathering processes.

The production of serpentine scarcely reaches a greater development, in the majority of cases, than to form a thin net-work along the cracks of the olivine; and this is seldom perceptible to the naked eye. On the most exposed surfaces, where the rock is superficially stained by the iron oxids of the decomposing olivine, the typical granular structure is still retained; and, with the exception of a small area at Buck creek, Clay county, there is no development of massive serpentine south of Waynesville.

But very different conditions have evidently prevailed somewhat further north; for in Buncombe, Madison, and Yancey counties we find these granular rocks largely altered to typical, massive

serpentine. The outcrops appear in the same form as found in the olivine rocks, and the characteristic chromite grains are always present. Under the microscope, thin sections often also show the original granular nature of the rock in the net-like or "mesh" structure of the fibrous serpentine bands that were first formed around the olivine grains. This structure is still more emphasized if, as is often the case, in the early stages of serpentinization, there was a separation of magnetite or other ferruginous material along these bands.

A serpentine retaining quite a large percentage of unaltered olivine is found on Ivy river, in Madison county. Sections of this rock, seen under the microscope, have the appearance of that shown in plate VI, figure 4; and, in some cases, the olivine grains are quite distinctly seen with the unaided eye.

However, most of the serpentine represented on the map, especially that in the vicinity of the French Broad river below Asheville, is massive and of light to dark green color, and is in every way similar to that of Maryland and Pennsylvania, in the northward continuation of the belt. In these States, it is quarried for architectural purposes, and may be seen in many buildings in the cities of Washington, Baltimore, and Philadelphia. There would seem to be no special reason why the serpentine of North Carolina should not be used in the same manner, especially where transportation facilities are good. Stone of good color is available in many of the localities indicated on the map; but thus far, no attempt has been made to utilize it.*

Many people in the corundum region of North Carolina use the term serpentine indiscriminately, and in most cases incorrectly, for any rock of the peridotite belt, especially when associated with corundum.

*See "Notes on Building and Ornamental Stone," by J. V. Lewis. 1st Biennial Report of the State Geologist, 1893, pages 101, 102.

(2.) SCHISTOSE ROCKS.

a. TALC-SCHIST, SOAPSTONE.

As already mentioned in the geologic sketch of this region, there is always a greater or less development of talc along the boundaries of the peridotites and pyroxenites, separating them from the gneisses of the country. But there are considerable masses of enstatite rock sometimes entirely altered to talc. Such rocks may, and sometimes do, retain the form and appearance of the original; but generally they have been rendered schistose by subsequent shearing.

Besides these larger masses, narrow strips of schistose talc are very generally developed along lamination of the gneisses as a continuation of the outcrops of the magnesian rocks; and these sometimes connect two or more lenticular masses of dunite or pyroxenite across intervals of two or three miles. The width of such strips seldom exceeds ten or fifteen feet, and is very frequently less. They are composed of rather pure, white and grayish talc, and are always schistose. Their chief importance, of course, lies in their close connection with the massive rocks. All the talcose rocks, frequently the chloritic schists, and sometimes even the peridotites are locally termed "soapstone," or "serpentine."

In many portions of the peridotite belt, especially in the northwestern counties of North Carolina, soapstone of the firmer and more massive varieties assumes considerable importance on account of its extensive local use. Its great resistance to heat makes it a most enduring material for the construction of fireplaces; and its use for this purpose is almost universal in regions where it can be readily obtained. It is easily cut into desired shapes with ordinary saws, axes, and planes, such as are used in wood-work. While the copper mine was operated at Ore Knob, Ashe county, great quantities of soapstone were used for furnace linings, all of which was cut from the neighboring peridotite belt in Ashe and Alleghany counties. This material also finds an extensive local use for tombstones on account of the ease with which it is shaped and lettered.

MAP OF THE
APPALACHIAN
CRYSTALLINE BELT
SHOWING THE DISTRIBUTION OF
PERIDOTITES AND CORUNDUM.
By J. V. Lewis, 1895.
LAKE HURON
L. ONTARIO
L. ERIE
MICH.
INDIANA
OHIO
PENNSYLVANIA
WEST VIRGINIA
KENTUCKY
TENNESSEE
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
ALABAMA
ATLANTIC OCEAN
Ohio River
Watertown
Rome
Albany
Chester
Boston
C. COD
Litchfield
New Haven
New York
STATEN ID.
Trenton
Philadelphia
Harrisburg
Hagerstown
Wheeling
Washington
Charleston
Lexington
Charlottesville
Lynchburg
Richmond
Norfolk
Greensboro
Raleigh
Salisbury
Knoxville
Asheville
Charlotte
Spartanburg
Laurens
Columbia
Augusta
Wilmington
C. HATTERAS
Rome
Gainesville
Atlanta
Birmingham
Dadleyville
Montgomery
LEGEND:
Schists and Gneisses.
Peridotites and other Basic Magnesian Rocks.
Corundum localities.
AM. BANK NOTE CO. N.Y.

b. CHLORITE-SCHIST.

Where corundum is found in connection with dunite, there is always more or less chlorite developed about the borders of the rock mass and through the larger joints; but the chlorite itself, in such cases, never assumes the importance of a rock. In certain localities, however, especially on the waters of the Tuckaseegee river above Webster, there are narrow strips of chlorite rock, comparable in many ways to those of talc described above, but in no way connected with known olivine rocks. They are apparently independent masses, usually schistose in character, and sometimes bear corundum. In these cases the corundum is surrounded by alteration zones of muscovite, but, besides the chlorite, the rock has no other prominent constituent. The chlorite rocks are often talcose, and sometimes pass over into the type described above. Whether talcose or not, they are usually known to the people as "blue soapstone."

5. DISTRIBUTION OF PERIDOTITES AND ASSOCIATED ROCKS.

(1.) IN THE APPALACHIAN BELT.

A great peridotite-serpentine belt, coextensive in length with the Appalachian mountain system (see map, plate II), traverses the crystalline schists and gneisses from Tallapoosa county in eastern central Alabama, where these rocks emerge from beneath the later formations to the southward, to Trenton, New Jersey, where they disappear for a space under the younger sedimentary rocks to the northward. Throughout this distance of over 800 miles, the peridotites are found along a narrow belt of disconnected outcrops with an approximate trend of north 45° east.

In the southern half of this belt, dunite is the prevailing type of rock, but in Virginia, Maryland, and Pennsylvania, it is represented only by the secondary forms—serpentine and talc rocks. Chromite is almost a constant accompaniment throughout the region, and in Pennsylvania, North Carolina, South Carolina, Georgia, and Alabama, corundum is also found in the same connection.

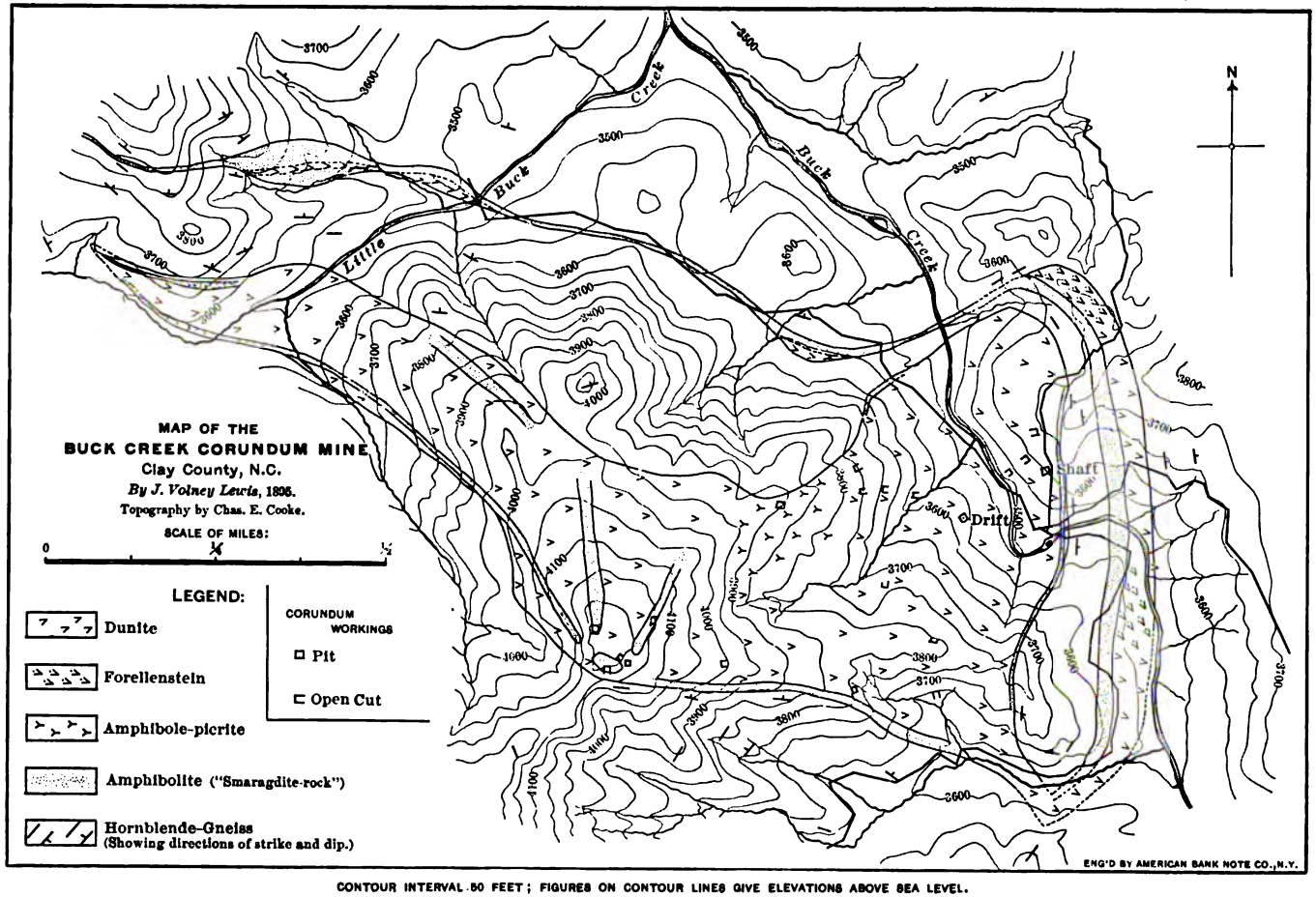
With the reappearance of the crystalline belt, we find serpentine again at Hoboken, New Jersey, and on Staten island. Other occurrences of a similar nature are found in northern New York, Massachusetts, Vermont, northern New Hampshire, and at Deer island on the coast of Maine. The distribution of these rocks is indicated on the accompanying map, plate II. The occurrence of corundum in these regions is discussed further on, but it may be stated here that, with two exceptions, it is not found with olivine rocks north of Pennsylvania. The two localities excepted are the emery deposits of Westchester county, New York, and the corundum found at Pelham, Massachusetts.

(2.) IN NORTH CAROLINA.

The highest development of these magnesian rocks is attained in North Carolina, where, in the southwestern connties, the outcrops are thickly scattered over a region nearly forty miles in width. In this region also—at Buck creek, in Clay county, and at Webster, in Jackson county (see plates III and V)—occur the two largest dunite outcrops of the whole belt, covering areas of approximately three-fourths and one-half a square mile respectively. It will be seen, however, that the amount of corundum bears no relation to that of the dunite; for very little corundum has been found at Webster, while the mine at Corundum Hill, (see plate IV) which has furnished a steady output of corundum for seventeen years, covers an area of only ten acres.

A more detailed description of localities is desirable in order to point out local characteristics and variations in the rocks that could not be represented on the map.

Along the southern boundary of the State, these rocks group themselves roughly into three sub-belts, located approximately in the valleys of the Chattooga, the Little Tennessee, and the Hiwassee rivers, though none of these retains its individuality for any considerable distance. In Union county, Georgia, two and a half miles south of the Towns county line, is the Track Rock corundum mine. The magnesian rocks outcrop here chiefly in the form of talcose chlorite schist. Little typical dunite is found,



CONTOUR INTERVAL 50 FEET; FIGURES ON CONTOUR LINES GIVE ELEVATIONS ABOVE SEA LEVEL.

though olivine grains are sometimes seen in the chlorite on the fresh fracture, and an altered dunite was found here by Mr. Francis P. King, of the Geological Survey of Georgia.* This outcrop is continued for two or three miles both north and south of the gap, by talcose rocks; and northward the line is almost continuous to the the Hamilton mine, which is located about a mile and a half south of the North Carolina line. Near the road, about a mile north of Young-Harris, is a small mass of forellenstein, and, so far as observed, this is the only exception to the prevalent talc-chlorite rocks of this line.

From this point, the line of outcrop drops back five miles to the east, and appears again in normal dunite a mile and a half north of Hiawassee. Here a long strip of laminated dunite crosses the road and may be followed for more than half a mile; and, a little further up Bell creek, two oval masses occur very near together, with dimensions of 400 or 500 feet. Near this, on the north slope of Bell knob, is a band of talc rocks interlaminated with gneiss, and the talc is found in almost a continuous line to the waters of Shooting creek in Clay county, North Carolina.

a. CLAY COUNTY.

Here considerable chlorite is found, gradually passing into less altered dunite near Shooting creek postoffice. After an interval of two miles, this line is again found at the foot of Chunky Gal mountain, composed of dunite and considerable schistose talc, in a strip rarely attaining a width of forty feet, but continuous for three miles across the mountain, and disappearing within a mile of the great Buck creek area.

Three miles above the mouth of Shooting creek, in the vicinity of Elf postoffice, are two other narrow strips of dunite very close together and lying parallel in the lamination of the gneiss for about a mile. Occasionally feldspathic phases are developed in these rocks, and in one place a peculiar lamination is found where feldspar and enstatite alternate with olivine in laminæ of half an inch to three inches in thickness. This lamination is almost at

*Bulletin No. 2, Geological Survey of Georgia, p. 93.

right angles to that of the gneiss, and the whole is enclosed in massive dunite. Accompanying the western strip almost its entire length, is amphibolite, varying all the way from almost pure feldspar to pure hornblende rock. The latter is of a brilliant grass-green, and sometimes bears beautiful red corundum. This strip differs also from the other in being continued northeastward for nearly three miles, by a narrow line of talc outcrops.

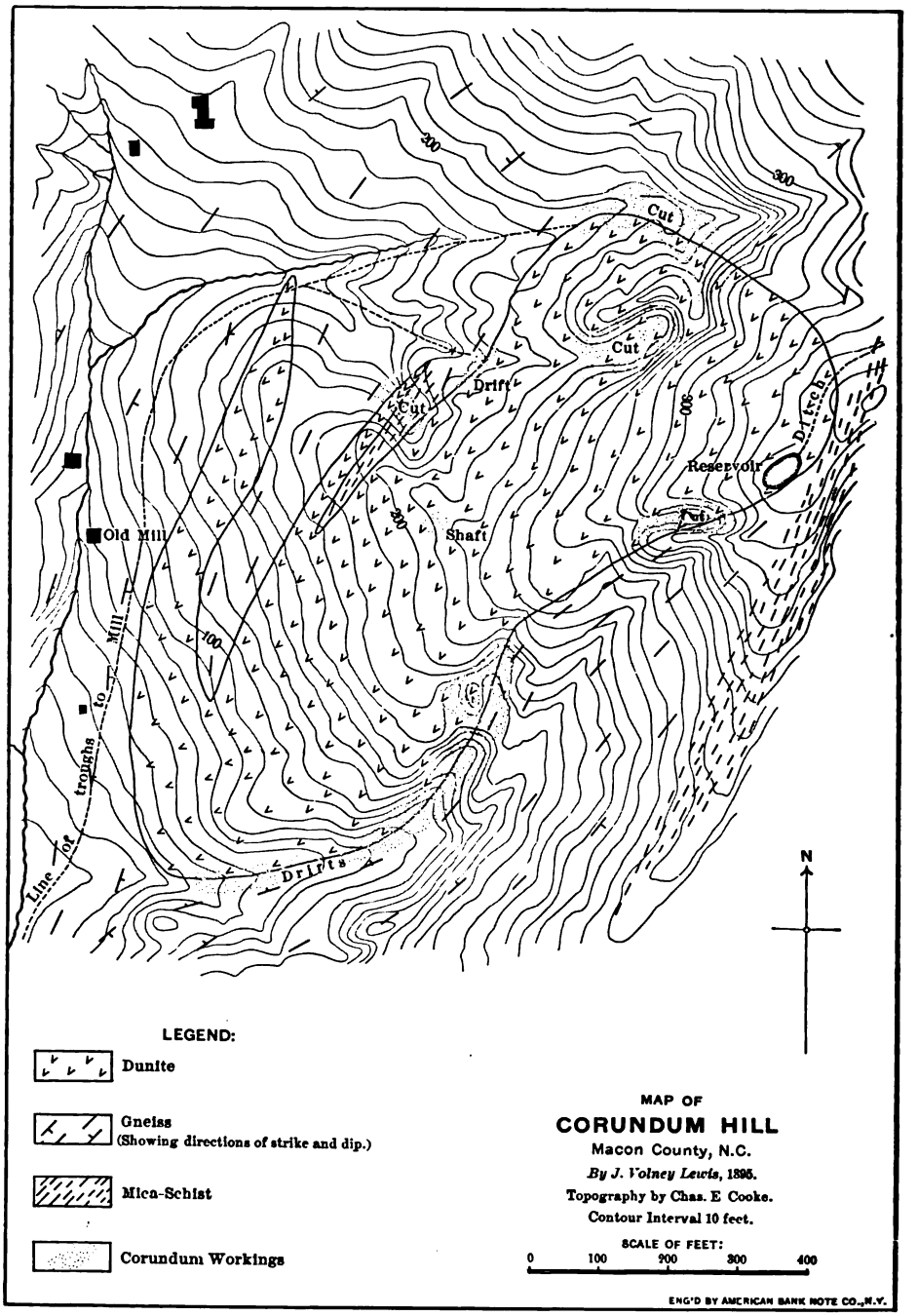
We now come to the Buck creek area, which is the largest compact mass of peridotite in the State, and in fact, the largest yet observed in the Appalachian belt. There is a greater surface exposure in the vicinity of Webster, but it is drawn out into considerable length, and in that respect differs markedly from that at Buck creek.

The form and extent of this outcrop are shown in plate III, which is reduced from a large-scale map made during the summer of 1894. Points of especial interest, which will be dwelt on more fully in a later report, are the amphibolite and forellenstein and their relations to the dunite, the arms (apophyses) passing into the surrounding gneiss, and the structure of the gneiss itself. In a general way these points are shown in the accompanying map (plate III) sufficiently well not to require further description here. The area of this outcrop is approximately half a square mile.

b. MACON COUNTY.

The broad region over which the peridotites occur in this county, as contrasted with the width elsewhere, especially northward, would seem to indicate that considerable disturbance has taken place here. Whatever theory may be adopted to account for the origin of the peridotites, the conclusion that a number of parallel breaks (fault-planes, or fissures) have been formed in this region is one that is readily suggested by a study of the map (plate I). A mile or two south of the State line, in Rabun county, Georgia, small lenticular masses of dunite and enstatite rock are developed on Bettys creek. Much of this enstatite is quite fibrous and abestiform.

On the road from Franklin, North Carolina, to Clayton, Georgia, and almost on the State line, is an outcrop of dunite with consid-



FIGURES ON CONTOUR LINES GIVE ELEVATIONS ABOVE AN ARBITRARY BASE—THE FLAT ROCK BED OF THE BRANCH NEAR THE SOUTHWESTERN CORNER OF THE MAP.

erable schistose talc; and for fifteen miles down the Little Tennessee river, numerous small, often entirely isolated, outcrops are scattered over the country. These arrange themselves approximately in lines and are represented on the map as continuous masses, where, strictly, there should be a number of small dots. Some of these are enstatite, and they are often represented on the surface only by the talc that has resulted from their alteration.

Between the Cullasaja river and the Jackson county line, an area on the spurs of the Cowee mountains is thickly dotted with typical oval masses of normal dunite, of which the well-known Corundum Hill outcrop may be taken as an example (plate IV). Many of the masses are somewhat larger or different in shape from this, but the variation is nowhere very great, and the same general type prevails. Plate IV is a topograhic map of Corundum Hill, and shows its most prominent characteristics. This rather blunt, lens-shaped mass of dunite has an extent of about ten acres, and the rock is laid bare over almost the entire surface. Enstatite, which is developed at the south end of this outcrop, is not usually found in the other places in this vicinity, though scattered grains and nodules of it are quite common.

As indicated on the map, corundum is found over this entire area between Walnut and Ellijay creeks, north of the Cullasaja, and considerable activity is manifested in the search for workable deposits.

c. JACKSON COUNTY.

In the line of strike of the gneisses of the Cullasaja region, are found, in Jackson county, a series of long strips of chlorite schist, as mentioned in the description of that rock, in the vicinity of the forks of the Tuckaseegee river. Similar narrow bands of talc schist are occasionally seen in the same region.

In some respects the dunite area at Webster (plate V) is the most remarkable outcrop of the whole Appalachian belt. In point of shape it is entirely unique, bearing no resemblance, as a whole, to the prevailing lenticular form. The line of outcrop traces an almost unbroken ellipse, mostly northeast of Webster, with a major axis of six miles lying north 25° east, and a minor axis of three

and a half miles. The width of exposure varies from a third of a mile at Webster to extremely attenuated strips of talc in several places; and on the eastern side five complete breaks occur, the smaller disconnected masses having the typical lenticular form.

Near its northern extremity, at Addie, an irregular mass projects into the gneisses within the ellipse; and a little further west, a gneiss area is entirely enclosed by slender strips of dunite and talc. Near Sylva, on the western side of the area, for a short distance, the deep soil covering rendered it impossible to determine whether the belt is continuous or not; and hence it is indicated there by a dotted line on the map. Plate V is reduced from a map of this region which has been prepared for publication in the final report on the corundum belt; but the most prominent features alluded to above are sufficiently well shown as not to require further explanation.

Another important peculiarity of this Webster area is the high development of lamination; and this is best seen in the larger outcrops about Webster and Addie. In its broadest portion, on the hillside facing the river at Webster, is the type locality of websterite, as mentioned in the description of that rock. It forms a strip within the dunite about 300 feet wide in its greatest development, and may be identified for a distance of about a mile. The only other locality where I have seen this rock is on the eastern side of this ellipse, about a mile above the mouth of Cane creek.

The peculiar form of the outcrop renders the structure of this area unusually interesting. The strikes conform to the outline of the ellipse, the dips, both inside and outside, are away from the centre, and, in general, steeper as we go outward. The directions of strike and dip are indicated by the symbols in the gneiss area, near the borders of the dunite.

Near the head of Cane creek, and within half a mile of the isolated dunite masses which form the eastern portion of the Webster outcrop, another line of dunite and talc schists begins, which is continued by a series of disconnected masses in a direction north 45° east almost to the Haywood county line, at Balsam gap. Near the gap, a very coarse grained phase is developed, which bears

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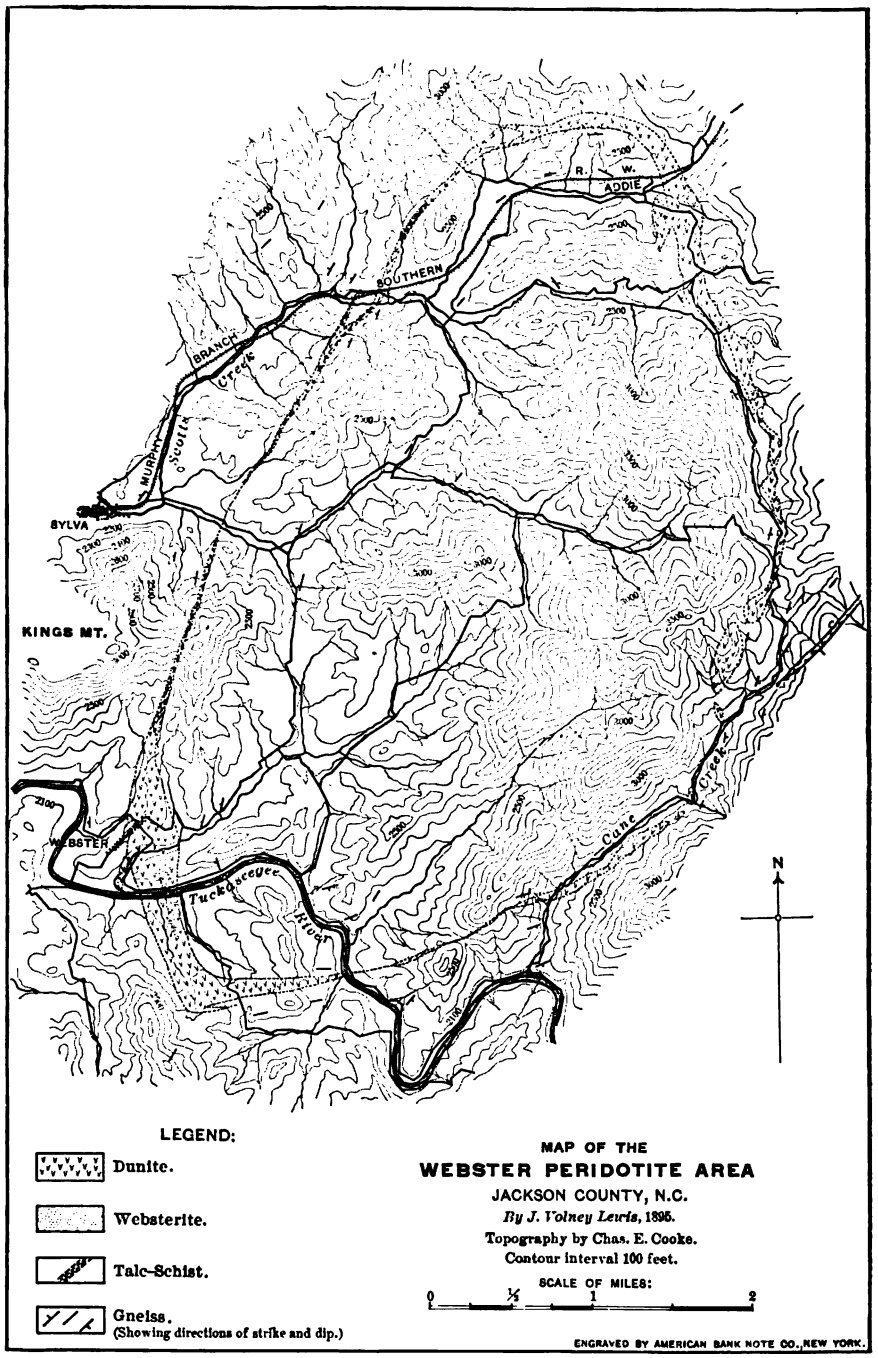

FIGURES ON CONTOUR LINES GIVE ELEVATIONS ABOVE SEA LEVEL

enstatite altered to talc, and good exposures are seen in railroad cuts.

In the southern portion of Jackson county, several small dunite areas are found in the vicinity of Glenville, and associated with these, talc and chlorite schists are developed in narrow belts. But dunite is found in much greater abundance in the region about Sapphire, including portions of both Jackson and Transylvania counties.

Directly southwest of these outcrops and in the direction of trend of the gneiss, is the Laurel creek corundum mine, in Rabun county, Georgia. This mine is very similar in many respects to that at Corundum Hill. The dunite outcrops in an oblong, somewhat irregular mass, covering an area rather larger than that of Corundum Hill; and, so far as observed, no arms branch off into the surrounding gneiss. The nature of the rocks is the same, though a much larger development of enstatite is found. The principal differences between these two mines are found in the minerals developed with the corundum; and further reference will be made to these in describing the modes of occurrence of corundum.

Several small areas of dunite and talc rocks are found between the State line and Sapphire, and quite a large area in the vicinity of the latter place is thickly dotted with dunite and enstatite rocks. Many of the smaller outcrops are necessarily merged into each other on the map.

d. TRANSYLVANIA COUNTY.

In the southwestern portion of the county, adjoining the Sapphire region of Jackson, the rocks are the same as those mentioned above, but enstatite rock becomes more and more prevalent as we pass northeastward into the valley of the upper French Broad river. Often the surface exposures of this rock are entirely altered to talc, and all the northwestern portion represented on the map by the talc-chlorite symbol is composed of narrow strips of talc schist, seldom exceeding twenty feet in width. Those nearer Brevard are similar strips of chlorite, becoming quite talcose towards the northeast. They are made up of several outcrops of "soap-

stone," as it is called, which could not be definitely connected by search for intervening exposures; but, on account of the small scale, they have been thrown into continuous lines on the map.

e. HAYWOOD COUNTY.

From the crest of the Balsam mountains, the Haywood-Jackson county line, a gap occurs in the peridotite belt, to the Pigeon river above Clyde—a distance of 15 miles. Just north of the river, scattering outcrops of soapstone occur over an area of several square miles. But peridotite does not appear till we reach the North Fork of Hominy creek, two and a half miles northeast of Canton, the railroad station at the crossing of Pigeon river. Here a strip of dunite several hundred feet wide and about half a mile long crosses the road near the creek. Another small lens occcurs near the head of the creek, and a strip of talc schist and still another dunite outcrop is found in New Found gap. A mile west of this line and on the waters of North Fork is the amphibolite outcrop in which is located the Presley corundum mine.

f. BUNCOMBE COUNTY.

For a distance of seven miles from the county line at New Found gap, the belt is not represented except for a small strip of talc which extends for a short distance from the dunite at the gap. Near Leicester, where the Asheville road crosses New Found creek, another mass of dunite occurs with dimensions not exceeding thirty by one hundred feet. A mile southeast of this, a small serpentine outcrop about ten feet wide is found and, very near this another serpentine mass about forty feet wide and about half a mile long.

Less than a mile further down New Found creek, two outcrops are found about 150 feet apart—one a strip of serpentine ten feet wide, and the other a typical dunite about thirty feet in width. Both of these outcrops have been cut across in search of nickel ore, and their nature is well shown. Decayed gneiss appears between, and, as far as the outcrops show, the two masses have no connection with each other.

For a distance of eight miles from this point, serpentine and talc are the only basic magnesian rocks found. The belt crosses the French Broad river a mile above Alexander—eight miles below Asheville—in two narrow strips of serpentine that may be seen north of the river on the Asheville road.

The river gorge here shows a fine section of the gneiss. It contains many granitic and other igneous intrusions and its lamination planes have been twisted and contorted in the most intricate manner. Doubtless the forces which produced these phenomena have had great influence in the hydration processes that produced the serpentine and talc in the dunite belt through this region.

Through the Flat Creek mountains, only strips of talc and a little serpentine are found, except one small outcrop of dunite five miles from the French Broad river, near the head of Flat creek. The talc outcrop is almost if not quite continuous to Morgan hill, two miles south of the Madison county line. At this point, it connects directly with a typical dunite mass which in a very short distance attains a width of 400 to 500 feet, and is continuous with about the same dimensions for three miles, ending with the Carter corundum mine in Madison county.

This strip is remarkable for its size and the constancy of its characters over so great a distance. Most of it is laminated, though less so than that of Webster, and nickel and chrome stains are quite prominent. Talc is highly developed along the borders, and chalcedony is found in rather larger quantities than usual. Corundum has attracted attention only in the northern portion of the outcrop, beyond Ivy river; and important deposits have been found only in the corner of Madison county, at the Carter mine.

The second parallel strip that was found at the crossing of the French Broad river is still traceable in the narrow strip of talc that appears at intervals from half a mile to a mile east of the principal outcrop.

g. MADISON COUNTY.

The Carter corundum mine is located in the north end of the outcrop last described, which is continuous from Morgan hill, in Buncombe county. Three miles north of this, serpentine again

appears on Paint Fork of Ivy river. Light green, massive rock predominates, but some portions show a considerable amount of unaltered olivine fragments visible to the naked eye. The outcrop at the road is about 100 feet wide and is continuous for about three miles toward Paint gap. At one point, a small mass of unaltered dunite occurs about one-eigth of a mile east of the serpentine, having a width of about fifty feet and interlaminated at the borders with gneiss. This outcrop shows no tendency to the development of massive serpentine.

The second and minor belt is represented in this county by dark green serpentine on the head waters of Terrys Fork, about two miles east of the main belt, in an outcrop about 200 feet wide.

Ten or twelve miles west of the principal peridotite belt just described, is a zone of scattering soapstone outcrops, which crosses the French Broad river two miles below Marshall. This zone seems to have its beginning in a series of similar rocks found north of Clyde, in Haywood county. In the southern part of Madison county, soapstone occurs on the headwaters of Spring and Sandy Mush creeks, and a number of outcrops are found along the course of the latter within a few miles of its mouth. It appears then on Little Pine creek, and on both sides of the French Broad river below Marshall. Outcrops occur at intervals as we pass up Walnut creek, and in a number of places on the waters of Big Laurel creek, on the north side of the county.

The chief constituent of these outcrops is schistose talc with more or less chlorite, the latter in a few places predominating, or occurring almost pure. But one important exception was found to this rule, and that is an outcrop two miles north of Marshall, on Walnut creek, at the county poor-house. The rock here consists largely of talc also; but scattered thickly through it are grains and crystals of olivine, varying in size from a small fraction of an inch to one or two inches in diameter. A rock exactly similar to this, near Philadelphia, except that the olivine has largely altered to serpentine, has been called "*perido-steatite.*" Several of the soapstone outcrops in this Madison county zone are full of small "rust-holes," as though similar olivine crystals had weathered out of it.

h. YANCEY COUNTY.

Crossing the mountains about Paint gap, only talc schists represent the belt till near Caney river the serpentine is again found on Possum Trot (McElroys) and Bald creeks.

Here it has the same general characters as that on Paint Fork, and the outcrops indicate masses of approximately the same dimensions. Beyond Caney river, no direct extension of this line is known, but two miles to the eastward, irregular outcrops of dunite occur on the waters of Prices and Banks creeks, accompanied by a little serpentine and a narrow strip of chlorite schist. Small talc outcrops are also found on the Green mountains north of Burnsville.

Four miles north of Burnsville, on Mine Fork of Jacks creek, a very prominent lenticular mass of peridotite appears. It is about half a mile long and 500 feet wide, and forms two small hills, one on either side of the creek. The rock is normal harzburgite of greenish yellow color, rather plentifully sprinkled with chromite grains, and much of it contains talc scales of the form and appearance of the original enstatite. A small peridotite mass occurs half a mile north of this, and then the line of outcrop swerves suddenly eastward, just before reaching the Toe river. For the rest of the distance within the county, it is represented only by narrow talc strips and occasionally a little serpentine.

A still smaller belt appears to the east of this line of principal outcrops, and this is seen in a narrow talc strip about two miles northeast of Burnsville, and in a mass of dunite on Chestnut mountain, four miles east of the locality on Mine Fork described above.

This last locality is perhaps the purest type of olivine rock yet observed in the whole belt. The outcrop is about 300 by 700 feet, oval in shape, and forms a hill about 200 feet high, with a perfectly barren rocky surface except for occasional bunches of sedge that grow in the crevices of the rocks. The longer axis of this mass lies north 10° west. Besides light greenish yellow olivine, the rock contains only a few disseminated scales of chlorite and, in places, small flecks and interlacing veins of talc. The rock has

weathered to a dull brown on the surface, but shows very little alteration of any other kind. At the contact with the mica schist in which it is enclosed there is a radial border of fibrous enstatite altered mostly to talc, but such borders do not follow the joints within the mass, as is often the case in other localities.

Ten miles west of Burnsville, in Egypt township, on the slopes of Sampson and Bald mountains, occurs a strip of rocks that must be considered as belonging here. At its southern extremity is located the Hayes (or Egypt) corundum mine, and the predominant rock is enstatite with a little dunite, the latter considerably altered to tremolite. Three separate masses of enstatite rock occur at the mine, and the line of outcrop is almost continuous across Bald Mountain creek. From this point narrow talc strips were found northward for a distance of four miles.

Again, on the eastern border of the county, we find a belt of enstatite rocks, and talc resulting from their hydration, along the valley of the South Toe river. Six miles south of the forks of Toe river, corundum is found with one of these outcrops on Bailey mountain. A mile east of this, there is a large outcrop of the talc-olivine rock ("perido-steatite") described above (see Madison county). The olivine crystals in this case are, however, much larger, some of them being several inches in diameter.

i. MITCHELL COUNTY.

Eight miles south of Bakersville, and just north of the ford of South Toe river, is an outcrop about one-fourth of a mile long and 300 to 400 feet wide, composed chiefly of dunite, though there is also considerable enstatite rock; and forming the transition between these two types, harzburgite is developed. This locality is very similar to that at the Woody place described next below.

Two and a half miles south of Bakersville is a large lenticular outcrop of dunite on what is known as the *Woody* place. It is about 300 by 600 feet and the long axis lies north 65° east. It is a light green dunite with considerable masses of enstatite rock. Very little chromite was seen. Cellular and compact chalcedony and nickel stains are abundant. The hillside which is composed of this rock is quite barren and rocky.

From this place a line of enstatite and talc rocks, outcropping at frequent intervals, extends up Cane creek. One small dunite mass appears near the summit of Grassy Ridge Bald, considerably to the nórth of the general line; but the original direction is continued by the large outcrops on North Toe river, six miles south of Cranberry, near the mouth of Roaring creek. This is a large, irregular area which is continuons for nearly a mile with a width of 150 to 200 feet.

Considerable chromite is found in some portions of the rock, and chrysotile (fibrous serpentine, commonly called asbestos) is highly developed at the north end of the exposure, just below the mouth of Squirrel creek. Another area of dunite occurs near this, on the side of Haw mountain.

At Bellevue, on the summit of Fork mountain, two miles south of Cranberry, dunite also appears in an outcrop about 200 feet wide and greatly altered to serpentine and talc. The outcrop can be traced by a strip of the latter for about one-fourth of a mile.

But here we evidently encounter the results of very great and complex earth movements, as shown by the manner in which the rocks of the Ocoee formation have sufferen folding, crumpling and general breaking up; and also by the presence of considerable bodies of massive rocks. In this region of intense confusion, no recognizable peridotites or related rocks have been observed for a distance of about sixteen miles from the outcrop at Bellevue mentioned above.

j. WATAUGA COUNTY.

Normal conditions are somewhat restored in the upturned edges of the gneisses on the western side of Rich mountain, just north of Boone. The first appearance of peridotite is observed in the road about two and a half miles west of Boone, where a typical yellowish dunite appears in a small outcrop. From this point outcrops occur at intervals in a curved line following the general trend of the mountain for a distance of four miles northward. More or less talc and asbestos accompany these occurences.

Near where the road crosses the mountain at the northern extremity of this line, a considerable body of chromite has been

removed in prospecting. It was in the form of a lenticular mass lying in the pure olivine rock, narrowing within a few feet of the surface to a small vein. These places constitute the last dunite outcrops found on the belt within the State. Further northward, enstatite becomes a predominating element, as in the region about Sapphire, in Jackson county, and in a number of cases constitutes the whole mass of the rock.

Just east of the northern extremity of this Rich mountain dunite, and about four miles north of Boone, an enstatite rock is encountered—in places altered into talc on the surface—forming, in some cases, masses of a hundred feet or more in width and traceable across the country continuously for about two miles. Other areas of less importance are indicated on the map, but it is scarcely necessary to mention them all in detail.

Of the other areas indicated on the map, one six miles east of Boone, on the crest of the Blue Ridge just north of Cook gap, is worthy of mention. Talc, bearing fine radiating actinolite, is the predominant rock in an outcrop about fifty feet wide and, perhaps, three or four times as long. But there are also large masses of dark green serpentine, the only occurrence of this rock that I have found north of Cranberry. About one-fourth of a mile northeast of this, another outcrop of soapstone of about the same dimensions is found on the estern slope of the Blue Ridge.

k. ASHE COUNTY.

An outcrop of importance, both on account of its unusual size and the type of rock represented, is found on the middle fork of Elk creek three miles from its mouth, and situated just east of the Watauga county line. Here an immense mass of harzburgite, the olivine-enstatite peridotite, forms heavy cliffs on the western slope of Black mountain, and great quantities of it have rolled down into the creek below. The rock consists of about equal parts of enstatite and olivine, and the texture varies from a uniform fine grain to that in which both constituents assume dimensions of three or four inches. Blocks of scaly chlorite, bearing red garnets one-fourth of an inch in diameter and occasional crystals of magnetite, are also found.

Four miles northeast of the outcrop just described, is another great mass of harzburgite, on Bee Ridge, a short spur on the east side of Elk Ridge. The mass is about a thousand feet wide, length undetermined, and presents a forked outline at the south end. Enstatite frequently predominates, and soapstone derived from it constitutes about half of the outcrop. This is sometimes schistose, though it often retains the structure of the mineral from which it is derived. Considerable quantities of this stone have been used for furnace linings in the copper works at Ore Knob. In the surrounding country, most of the fireplaces and many of the chimneys are built of it; and it is found quite suitable for these purposes, both on account of its fireproof qualities and the ease with which it is worked. Soapstone outcrops have been worked at intervals, along the flanks of Elk Ridge, for three or four miles north of this place.

Other small outcrops of soapstone, which have had some local application, are found on Negro mountain, just south of Jefferson, and one and a half miles north of Jefferson, at Phœnix gap.

l. ALLEGHANY COUNTY.

The first appearance of peridotite in this county is found three miles south of Sparta, near Little river, where soapstone is found in the road to Whitehead. From this point, a line of disconnected harzburgite outcrops follows the general direction of Little river almost to the Virginia line. It is typically developed about a mile east of the mouth of Pine Swamp creek, also just north of the mouth of Glade creek, in the great bend of the river, and south of the river, at the mouth of Brush creek. It next appears at Ennis, on Crab creek, and is found in almost a continuous line up the north fork of this creek, in a direction about north 50° east, to the Virginia line. The same rock is said to occur almost continuously for fifteen miles further in the same direction.

This rock has about the same nature as that at Bee Ridge, in Ashe county, described above. All stages are found between pure talc and nearly pure olivine rock, but the latter is never quite free from a certain perceptible amount of talc or enstatite. A coarse lamination is generally discernible, and the purer steatite

portions are usually schistose. The latter also frequently bears a considerable proportion of carbonates; and the numerous "rust-holes" in some portions of the outcrops are doubtless due to the weathering out of these minerals and olivine.

6. CORUNDUM.

For a complete description of the chemical, physical, and crystallographic characters of corundum, the reader is referred to Dana's System of Mineralogy, or to any good text-book on the subject. Only the most important features are related here, and technicalities, while not entirely avoidable, are dispensed with or explained as far as practicable, for the benefit of the general reader.

(1.) CHARACTER AND VARIETIES.

Next to diamond, corundum is the hardest substance known in nature, and on this property, as more or less modified by other qualities named below, depends its commercial value. It crystallizes in the rhombohedral division of the hexagonal system; but the six-sided prism is usually the most prominent form, and the crystals often appear to have the complete hexagonal symmetry (see figures 1, 2 and 3). Sometimes, however, the rhombohedron is quite prominent, but it is usually developed only in small faces truncating the alternate corners of the prism and basal plane or pyramid.

Small crystals are usually quite perfectly formed, but the larger ones are generally rough and irregular, with many of the faces deeply corrugated. Figures 1 and 2 show the hexagonal form as effected by rhombohedral and basal parting, respectively. Figure 3 is a crystal with rhombohedral parting well shown by the faces it has produced on the prism. Figure 8 is a common form of wrapped crystal.

Strictly speaking, corundum has no cleavage, but two forms of parting, often erroneously called cleavage, are frequently met with. This parting is due to multiple twinning, and the form

most commonly seen is that parallel to the rhombohedral faces, which are inclined to each other at an angle of 93° 56′, thus breaking the crystal into almost cubical blocks, (see figures 1, 3, and 7). The other form of parting is parallel to the basal plane, and crystals in which it is developed break square across into a number of thin segments, often resembling buttons, (figure 2). Crystals or masses in which no parting is developed break with a rough, uneven fracture.

Fig. 1.

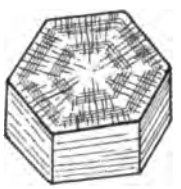

Fig. 2.

Fig. 3.

Fig. 1.—Hexagonal crystal of corundum showing rhombohedral parting. (From Tschermak's Mineralogy.)

Fig. 2,—Corundum crystal showing basal parting and concentric zonal arrangement of colors. (Tschermak.)

Fig 3.—Corundum crystal from Egypt mine, Yancey county, showing hexagon terminated by rhombohedral parting planes. One-fourth natural size. (Drawn from a photograph.)

Corundum sometimes appears in masses without crystal form, though crystalline in structure, and such masses may have either form of parting described above. Crystalline granular aggregates are also sometimes met with.

All the foregoing varieties of form and crystallization are subject to great variation in color—gray, blue and red being the most common. Corundum is usually more or less translucent, but seldom transparent. The more strongly colored varieties are pleochroic; that is, they show different colors for light passing through them in different directions.

Corundum has a specific gravity of 3.9 to 4.1, which is equivalent to saying that it is about four times as heavy as water. Of the minerals associated with it, only chromite and magnetite are heavier, garnet and spinel are about the same weight; olivine,

chlorite, hornblende, tourmaline and margarite are not so heavy; while quarty, feldspar, serpentine, and talc are much lighter.

Professor Dana, in his description of the varieties of corundum, says: "There are three subdivisions of the species prominently recognized in the arts, and until early in this century regarded as distinct species; but which actually differ only in purity and state of crystallization or structure."*

The three varieties mentioned are; 1. Sapphire, 2. Corundum, 3. Emery.

1. SAPPHIRE includes all those transparent and translucent kinds which are of good colors and useful as gems. Jewelers designate the various gems according to colors: the red is the oriental or true *ruby*; the blue is the *sapphire*; the yellow is the *oriental topaz;* the green is the *oriental emerald;* the purple, the *oriental amethyst;* and the opalescent variety showing a six-rayed star of light is called *asteria*, or *star sapphire.* North Carolina has produced the sapphire variety of corundum in every known color.

2. CORUNDUM, as the term is used in the arts, "includes the kinds of dark or dull colors and not transparent, colors light blue to gray, brown and black." This is the rough material which forms the bulk of the product of the North Carolina mines.

3. EMERY is an intimate mixture of granular corundum and magnetite or hematite. This is the form of much the greater part of the corundum used in the arts; a fact which is due to its comparative abundance and cheapness in Asia Minor and the Grecian Islands, while corundum is obtainable only in much smaller quantities and at greater expense. Emery is mined at Chester, Massachusetts, and has been obtained in small amounts from Westchester county, New York. It was found in Guilford county, North Carolina, in 1871, by Dr. Genth, (see index reference, *Emery*), and has been recently reported from a locality in Macon county, North Carolina, but, so far as I am aware the material has not yet been examined, so no further statement can be made in regard to it at present.

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*Dana's System of Mineralogy, 1892, page 212.

(2.) USES OF CORUNDUM.

The use of the sapphire variety for gems has already been pointed out in the description above. The red colors are most highly prized for this purpose, and especially that particular shade known as "pigeon-blood." Fine specimens of two or three carats in weight are equal in value to the diamond.

Corundum and emery are used for the same purposes, and in both the value is due to the hardness as applied to cutting and polishing metals, glass, stone, and all hard substances. The material to be used for polishing is first crushed and then sorted according to size of grain by passing through sieves. For most cutting and grinding purposes, the granular material thus obtained is made into a kind of dough with some cementing material, then moulded into the form of a grindstone and baked. Such artificial stones are called corundum wheels or emery wheels, according to the material of which they are made, and are extensively used in all kinds of metal working, especially the iron and steel industries.

(3.) NORTH CAROLINA CORUNDUM.

The gem varieties of corundum were the chief attraction for the early prospectors and miners. The mine at Corundum Hill, in Macon county, the story of which constitutes the greater part of the history of corundum mining in the United States, was opened and worked for a number of years as a gem mine. Some of the material that came from this mine and other localities in the State has attracted considerable attention, as may be seen from the following mention by Mr. George F. Kunz:

"In variety of color the North Carolina corundum excels. It is found gray, green, rose, ruby-red, emerald-green, sapphire-blue, dark blue, violet, brown, yellow, and of intervening shades, and colorless" "Many specimens [from North Carolina] have been cut and mounted, especially of the blue and red shades, and make good gems, though not of the choicest quality. Several rubies of 1 carat each have been found; a blue sapphire, 1 carat in weight,

is in the United States National Museum at Washington, and a series of fine red and blue crystals has been deposited there by Dr. H. S. Lucas."*

In several localities, as on Ellijay creek, in Macon county, crystals of a peculiar brown corundum with a beautiful chatoyant lustre have been found. "These (when cut *en cabochon*) all show a slight bronze play of light, and under artificial light they show well defined stars, being really asterias, or star-sapphires, and not cat's eyes, as might seem at first sight to be the case."†

Although the principal work in the mining region is now concentrated on the search for commercial corundum, still there is a considerable interest shown in some sections in prospecting for gems; and Mr. Kunz writes again in 1893: "The finding of small rubies of fairly good color in Macon county, North Carolina, gives ground for the belief that larger and better stones may be found there by more extended development."‡

Commercial corundum does not occur in all the varieties of color that are found in the gems, but there are differences of texture and purity that have no less important bearing on the value of the product than color and transparency in the gems. As mentioned above in describing the varieties, this class includes all those dull and dark colored kinds which constitute the principal product of the mines. The colors are generally gray, or some shade of blue, or mottled white and blue; but the variations in texture are much more important than those of color. The different mines of the State produce every known variety: massive or "block" corundum, crystal corundum, and the fine granular or crystalline variety called "sand" corundum. And all these are sometimes found associated in the same immediate locality or even the same mine. Each mine has its own peculiar characteristics, however, and a kind of family resemblance runs through its whole product. This fact is well recognized by the miners, and they can frequently ascribe a specimen to its proper locality by its general appearance.

Corundum from some localities is chiefly six sided crystals, often

*George F. Kunz, Mineral Resources of the United States, 1892, pages 760, 761.
†George F. Kunz, Gems and Precious Stones of North America, 1890, page 47.
‡George F. Kunz, Mineral Resources of the United States, 1893, page 680.

tapering toward the end like a barrel—hence, we sometimes hear the term "barrel corundum"—and these crystals may or may not have one of the forms of parting developed. If parting is absent or only developed to a slight extent, the crushed product will be solid and tough, even in the coarser numbers; while, if it is very highly developed, the coarse numbers and sometimes also the medium and finer sizes will be full of these parting planes along which it will easily crumble down in use. Besides producing a defective grain, there is always considerable loss in crushing from the production of an unusual amount of "flour."

The massive or "block" corundum may have the same defects, though this is usually not the case, and hence such material, when in sizes suitable for crushing, produces a good tough grain. But the difficulty encountered in working such corundum lies in the size of the masses, which are frequently intergrown with feldspar and hornblende into blocks so tough that they cannot be profitably broken and crushed. This is the case with some of the material mined at Buck creek, in Clay county. This variety is also found in veins of tough, compact materials which render its removal from the mine a source of considerable expense.

Sand corundum consists of small crystals and irregular grains, which are developed in the soft vermiculites surrounding the peridotites, and hence are always easily dug out and the corundum obtained by washing away the lighter minerals. This variety is not subject to the difficulties and defects of the other two, but, as there is considerable variation in the size of the grains, it is impossible to remove all the lighter minerals by washing, and, of course, the magnetite and chromite cannot be thus removed.

Corundum in place in the rocks is subject to numerous alterations by which its hardness is impaired even in incipient stages; and this property is entirely lost in the complete alteration, which produces a series of aluminous minerals of little or no value as abrasives.

It is a well known fact that chemical action takes place much more rapidly on small grains than on large ones, owing to the greatly increased proportion of surface exposed: hence, sand corundum is more subject to alteration than the larger masses. The sand may

be in some cases only the remnants of larger masses which have disappeared through this means. Still, sand corundum is the kind most sought by the miners, and the usual presence of more or less crystal corundum along with it makes up to a certain extent for its lack of purity. These two forms constitute the product of the mine at Corundum Hill.

(4.) MODES OF OCCURRENCE OF CORUNDUM.

Professor Zirkel enumerates the following modes of occurrence of corundum as a *rock constituent*: Corundum in small, fine grained aggregates is the chief constituent of emery. Otherwise, it occurs only occasionally as an accessory in granites, gneisses, granular limestones and dolomites, in the amphibolites of northwestern Austrian Silesia (largest hazel-nut size, white or blue grains), in the cholorite schist of Nischne-Issetsk in the Urals, in the graphite of Mühldorf, near Spitz, in Lower Austria; as blue sapphire in several basalts, where it is perhaps originally a remnant of molten inclusion; often with spinel, rutile and sillimanite. Worthy of note is the occurrence as a contact product of the diorites of Klausen, in Tyrol. It is also observed as altered foreign inclusions or as real accessory masses in certain eruptive rocks, often with cordierite, spinel, andalusite—as inclusions in the andesite of the Eifel, and similarly in tonalite. Further it appears scattered through a contact product of quartz-mica-diorite on quartz-phyllite in Val Moja. Similarly in the kersantite of Michaelstein, Harz.*

Besides these occurrences as a rock constituent, corundum is found in large quantities in feldspar veins and associated with chlorites in the peridodtites and serpentines of the Atlantic States of America; and in areas of crystalline rocks in many parts of the earth's surface, in the gravel-beds of streams. Except the occurrences in granular limestone, in graphite, and in association with volcanic rocks, all the various modes enumerated above have been observed in North Carolina. These will be described briefly in the following order:

*F. Zirkel, Lehrbuch der Petrographie, Leipsic, 1893, page 416.

a. Associated with peridotites; *b.* In chlorite schist; *c.* In amphibolite; *d.* In dunite; *e.* In gneiss; *f.* In gravel deposits.

a. CORUNDUM ASSOCIATED WITH PERIDOTITES.

The occurence of corundum in the State, with few important exceptions, is in association with olivine rocks (peridotites), though rarely occurring in the body of such rocks. It is found in the zone of chlorites and vermiculites developed between the peridotites and the gneisses of the surrounding country, and sometimes near this zone in the gneisses themselves. In some cases this border zone of chloritic minerals carrying corundum has developed along the joints of the peridotites to the very center of the mass. Such a condition is shown in a number of openings at Corundum Hill, though mining operations have been chiefly confined to the border zones. (See figure 6.)

These zones vary exceedingly in thickness, from ten or twelve inches to as many feet, and the proportion of corundum is scarcely more constant, though bearing no relation to the dimensions of the "vein". In places the chlorites are thickly studded with corundum almost from wall to wall, and sometimes this condition prevails for a considerable distance; then the corundum-bearing portion will narrow down to a thin strip in the middle, or perhaps disappear entirely, to be encountered again only after a considerable amount of barren material has been handled.

There is a prevailing impression that peridotite always occurs in hornblende-gniess. While this is frequently the case it is by no means universally true, as a microscopic examination shows some of these enclosing rocks to be normal gneiss; that is, composed of quartz, feldspar and mica (the mica being chiefly biotite). In other cases, the country rock is mica-schist.

A gneissoid rock resulting from the lamination of the bright green hornblende rock found at Buck creek, in Clay county, and elsewhere, is closely associated with the peridotites of these localities; but it is here regarded as a member of the peridotite group, and is not classed with the country rocks.

The gneiss of this region, wherever found in contact with the

peridotites near the surface is considerably decomposed, crumbling easily into a loose sand, though retaining a fresh appearance and the original structure of the unchanged rock so far as may be seen with the unaided eye.

In the description of the secondary products found in connection with the alteration of dunite, mention was made of the enstatite casing which often surrounds the jointed masses of the rock. In most cases, it is quite clear that these casings are closely connected with the chloritic zones that bear corundum. They are composed of enstatite, often fibrous and usually altered more or less to talc; and the structure is radial, or parallel, the fibres standing normal to the outer surface of the dunite block enclosed. In all cases observed, the enclosed rock is more or less altered, and frequently to such an extent that only a soft ochreous, clay-like mass remains, though the casing may be tough and apparently fresh. These casings often contain more or less chlorite, and especially towards their outer portions; furthermore, they are never developed except in places where chlorite is also formed along the borders and more prominent joints of the peridotites; and, *vice versa*, some slight development, at least, of such enstatite always lies between the chlorite and the olivine rocks.

The whole zone, consisting of chlorite, vermiculite, talc, and the enstatite border is frequently sheared until all original structure is replaced by a high development of schistosity.

A number of other minerals are always present in minor proportions, varying in importance in the different localities. Some variety of amphibole, pyroxene, spinel, and tourmaline are frequently observed; staurolite, diaspore, and anthophyllite are occasionally seen; and, where the corundum is associated with feldspar, margarite and zoisite are frequent accompaniments. Muscovite, margarite, and other minerals that so often form the wrapping of corundum crystals, appear to be in many cases undoubtedly the results of alteration of that mineral, as indicated by the researches of Dr. F. A. Genth.

The green and yellow micaceous minerals, known respectively as chlorite and vermiculite, have been divided into several more or less

definite species based on chemical analyses. Lucasite, kerrite, culsageeite, jefferisite, wilcoxite, etc., are some of the names that have been given to the yellow and brownish minerals; but the distinctions are almost purely chemical, and the names are of no practical value in the field examinations; and, in most cases, their use would tend only to confusion. These are all grouped here under the name *vermiculite.* Pennine, clinochlor, prochlorite, corundophilite, etc., are some of the more important subdivisions of the chlorite group; but the same condition exists here as in the vermiculite group, so far as field distinctins are concerned, and the term *chlorite* is used for all green colored micaceous minerals associated with corundum and the olivine rocks.*

In the midst of these chlorite zones, corundum is sometimes found in veins of feldspar, as at Buck creek, and with amphibole rocks in Iredell county. In rare cases quartz is intergrown with the feldspar, forming a true pegmatite. Such a vein, without corundum is found at the Hamlin prospecting, on the head-waters of Ellijay creek, in Macon county.

b. CORUNDUM IN CHLORITE SCHIST.

An occurrence in some respects similar to that in the chloritic zones about peridotites, is found in the long belts of chlorite schist that traverse the country ten to twelve miles southeast of Webster. Chloritic rocks here, which sometimes attain a width of several hundred feet are traceable across the country for several miles. Green, scaly chlorite is almost the only constituent of these rocks, though sometimes they are flecked with small white grains of feldspar, and occasionly amphibole needles are seen. The chlorite is in small scales, never very coarse, as is sometimes the case in the zones about peridotite, and often they are so minute as to impart quite a compact appearance to the rock.

In one of these belts, on Caney Fork of Tuckaseegee river, corundum is disseminated through the chlorite in small rounded masses, ranging from an inch in diameter to minute grains. In

*A careful investigation of the chemical and mineralogic relations of corundum and its associated minerals is now being pursued by Mr. Joseph H. Pratt, of Yale University and the most of these minerals are here referred to only in a general way.

these cases, the chlorite is not so tough and compact as elsewhere, and the corundum is invariably wrapped in a coating of white mica, usually in radiating scales perpendicular to the outer surface of the corundum. The mica coating is exceedingly thin in some cases, but it is so variable that many nodules are composed almost entirely of it with only a small grain of corundum in the centre. The secondary nature of this mica and its derivation from the corundum can scarcely be doubted.

C. CORUNDUM IN AMPHIBOLITE.

The beautiful grass-green hornblende rock, which forms important dike-like masses at various peridotite localities in Clay county, was described above among the massive rocks associated with peridotite (p. 28). Besides the green hornblende and the anorthite which constitute the principal constituents of the rock, there is always present, in the corundum-bearing phase, microscopic grains of picotite, and the smaller grains of corundum are usually intergrown with irregular masses of this mineral and enclose many minute particles of it.

The corundum ranges in size from the minute microscopic grains to large masses of several inches in width, and is usually laminated or possesses a parting according to the rhombohedron, which breaks it into small, nearly cubical blocks. It ranges in color, too, from almost white to deep ruby-red, most of it being of quite a decided red color. Some portions of the rock are thickly studded with corundum, and boulders of this kind have been gathered from the surface at Buck creek and hauled on wagons to Corundum Hill to be crushed for separation. It has furnished some handsome cabinet specimems, the contrast of the bright red and green colors producing a striking effect; but it is an exceedingly tough rock and is not likely soon to become a commercial source of corundum.

The corundum that has been found in place in the vicinity of Statesville, Iredell county, is developed in the joint-planes and along the borders of coarse hornblende rocks, much in the same manner as that with dunite at Corundum Hill and elsewhere in the more westerly counties. These hornblende rocks appear in

the gneisses somewhat as the peridotites, so far as may be judged from the meagre outcroppings available, and the corundum is found with fine brown, scaly vermiculite, which is developed in zones from a few inches to three or four feet in thickness, along the borders, and through irregular joints in the hornblende rock (See figure 4). In one or two instances, feldspar veins five or six inches thick, sometimes altered to kaolin, were observed in the midst of the vermiculite zones. This feldspar often bears corundum also, though in prospecting most of it was found with the vermiculite. The corundum is in crystals and rounded masses of crystals clustered together; sometimes margarite accompanies it, and large masses have been found on the surface in this region made up of these two minerals.

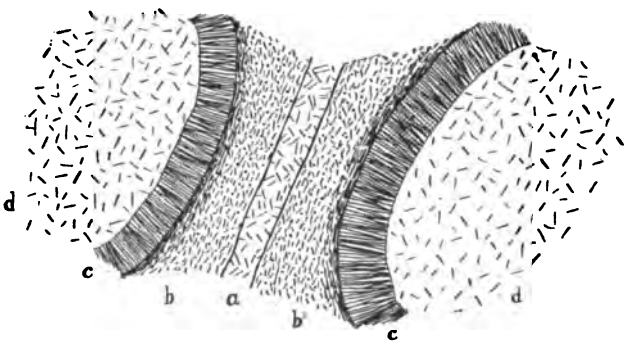

Fig. 4.

Fig. 4. Diagram illustrating the mode of occurrence of corundum in amphibolite at Hunter's, seven miles west of Statesville, Iredell county. *a*, Feldspar vein, (not always present) sometimes carrying corundum; *b*, Fine scaly vermiculite with crystals and lumps of corundum; *c*, Radiating border of actinolite enclosing large blocks of (*d*) dark green hornblende rock.

Still another point of similarity to the occurrences in connection with peridotite is found in the radiating borders that intervene between the corundum-bearing vermiculite zones and the massive rock. In this case, the radiating border is composed of a green horneblende similar to actinolite, instead of the enstatite. Similarly, the rounded blocks thus inclosed are often almost completely decomposed; so that we find, on breaking through this radial

casing, only a mass of ochreous clay bearing occasional needles of horneblende and scales of brown vermiculite.

d. CORUNDUM IN DUNITE.

Thus far I have observed but one instance of this association; and, so far as I am aware, it is entirely unique. This was found at the Egypt mine on the western slopes of the Sampson mountains, in Yancey county, by Mr. U. S. Hayes, who was prospecting at the time of my visit. I am indebted to him for two of the best specimems collected, one of which is shown in figure 5. It consists of a hexagonal crystal of corundum completely surrounded by granular dunite, with none of the chloritic minerals which usally intervene. The dunite is not quite fresh, being stained yellowish brown and rather friable. A little muscovite is developed along the basal parting planes of the corundum, as is often the case in other occurrences.

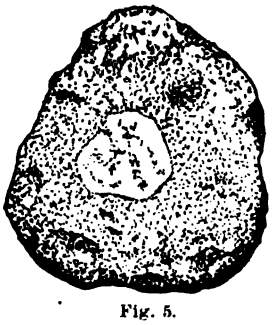

Fig. 5.

Fig. 5. Corundum crystal in altered dunite. From Egypt (Hayes) mine, Yancey county. One-half natural size. (Drawn from a photograph.)

With one *possible* exception, so far as I am aware, this is the first instance of such anomolous mineral association yet recorded. In enumerating the minerals of the Buck creek corundum locality, in 1875, the late Dr. C. D. Smith states that he found "chrysolite attached as an enveloping matter to considerable masses of corundum;" * but as neither Dr. Smith nor any of the numerous writers on this subject during the succeeding twenty years have made any further mention of this extraordinay discovery, it may

*Report of the North Carolina Geological Survey, 1875, Appendix page 95.

be fairly assumed, I think, that this passage refers only to the ordinary occurrence of corundum in the chlorite zones developed within the peridotite and along its borders.

e. CORUNDUM IN GNEISS.

In the same belt of crystalline rocks that carries the peridotite, but apparently in no way connected with the latter, corundum is found in a number of localities in the ordinary gneiss of the country. Five years ago Dr. Genth * described, as a new mode of occurrence for corundum, that discovered in the mica schist region of Patrick county, Virginia. The schists are sometimes garnetiferous and gneissic, and the corundum is associated with andalusite, cyanite, chloritoid, mica, etc. The schists were intersected with granite dikes, and the corundum was found near these in crystals and rounded masses on the surface.

In the North Carolina localities, corundum occurs in place in the gneiss in nodules of half an inch in diameter and smaller, and wrapped in a sheath of radiating muscovite, similar to that in the chlorite schist described above. None of the accompanying minerals described by Dr. Genth were observed, and but for the presence of these nodules, the rock seemed to be in every way normal gneiss. The nodules, on account of their resistance to the decomposing forces of the atmosphere, always stand out prominently on the weathered surface; and they are often present in such proportion as to thickly stud these surfaces with little white and grayish knots.

In one instance, however, the corundum-bearing gneiss is associated with basic magnesian rocks, though such has not yet been shown to be the case in other instances. The basic rock referred to here occurs on the head waters of Shooting creek, in Clay county, and consist largely of fine grained green horneblende and hypersthene—the latter somewhat predominating. The sections of this rock have not been sufficiently studied to determine whether the horneblende is primary or secondary, but the preponderence of the hypersthene would give ground for calliing it hypersthenite. This rock cuts through the gneiss in two dikes about ten feet thick

*F. A. Genth, Am. Jour. Science, 3, xxxix, 1890, pages 47, 48.

and about 500 or 600 feet apart. The Corundum is found in the gneiss between, intimately associated with a small pegmatite vein and a band of very black mica.

Just beside one of the dikes also, corundum was found in a zone of fine scaly brown mica. This corundum is in nodules and, like that in the gneiss between the dikes, has two systems of parting well developed.

In other localities, no such relation to magnesian rocks has been observed. The covering of soil and decomposed rock is, however, very deep in some places, and quite sufficient throughout most of this region to render the outcrops rather obscure.

On the western side of Chunky Gal mountain, bands of brown mica, bearing lumps of granular garnet, and both carrying more or less corundum, are found in the gneiss. So far as determinable at the time of my visit, the corundum here has no connection with peridotite or similar rocks.

f. CORUNDUM IN GRAVEL DEPOSITS.

It is well known that the gem varieties of corundum are found chiefly in the soil and gravel beds of Burma, Ceylon, and other regions of southern Asia. Along with these, the common forms of crystalized corundum are also found ; and, in some of the localities, the mineral has been traced to its origin in the crystalline rocks.

The gravel beds represent the result of ages of concentration. While the rocks have been slowly decomposing and crumbling away through the agencies of air and water, the stream beds furnished a natural system of sluices in which the heavy and more resistant minerals, including corundum, have been caught and retained, while the lighter material has been carried out to the sea. Hence, although the corundum gems may have been quite rare in the original rock, they are found in these gravel deposits in comparitive abundance; and even when the original source is found, the gravels still remain the principal commercial source.

Most of the corundum localities of North Carolina have been found through the discovery of fragments in the soil or in beds of streams; and it is a favorite method with prospectors to wash the

gravels of stream beds for corundum, much in the same manner as search is made for gold. Similarly, corundum crystals have been ploughed up in bottom lands, and further investigation has revealed gravel beds, often of considerable extent, which usually bear several varieties of corundum. Search up the stream and its tributaries till no further trace is found and then up the adjoining hillsides, has in many instances brought to light the source of these valley deposits; but, in a number of cases, such search has proven, thus far, fruitless; and we are led to the conclusion that the corundum must have been concentrated from rocks in which it is only a rare constituent.

Several such deposits, in Macon and Jackson counties, have furnished ruby-colored corundum of nearly every shade, and considerable attention has been devoted to the search for gems. Occasionally pieces are found sufficiently transparent and free from flaws to be cut into fair gems, though most of it is too much clouded and the parting too highly developed to be of any value except as mineral specimems. The principal object of the recent work in these gravels has been to locate the original source of the material in the hope that the finer specimens may be found in sufficient quantity to establish gem mining on a profitable basis.

Small grains and crystals of corundum are found in the gold placers of Rutherford, McDowell and Burke counties, but they are not considered of sufficient importance to be indicated on the map.

(5.) DISTRIBUTION OF CORUNDUM.

As indicated above, in the description of the modes of occurence, the home of corundum is in the highly crystalline rocks, and chiefly in the region of gneisses. This is true of all occurrences that attain to any but purely scientific interest.

a. IN THE APPALACHAIN BELT.

In describing the distribution of peridotites, mention has already been made of the occurrence of corundum in Pennsylvania, North and South Carolina, Georgia and Alabama. In these states, the corundum localities are found along the peridotite belt indicated on the general map (plate II, p. 32). Other localitites are found as

indicated above, which are not intimately connected with these rocks; but thus far none of these, except the emery of Chester, Massachusetts, has become of economic importance.

CORUNDUM IN ALABAMA.—The Appalachain crystalline belt passes under the Cretaceous and later sedimentary formations in the central part of the State near Montgomery. Representatives of the peridotite belt have been found in the vicinity of Dudleyville, in Tallapoosa county, and corundum has been found in fragments on the surface both in this and Coosa, the adjoining county on the west. A little search would doubtless reveal the presence of peridotite, and perhaps also, corundum, to the very borders of the crystalline rocks.

CORUNDUM IN GEORGIA.—A series of scattering deposits extends the peridotite belt through this State in a northeast direction, passing in a general way up the valley of the Chattahoochee river to the western extremities of North and South Carolina. Along this line, corundum has been found in the following counties: Rabun, Towns, Union, Lumpkin, Habersham, Hall, Cobb, Paulding, Douglas, Carroll, Heard, Troup, and somewhat off the line to the east, in Walton. One occurrence is reported in Forsyth county in a region of mica schist and garnetiferous horneblende gneiss. Considerable work has been done along this belt in the nature of prospecting, and for a number of years, a productive mine was operated at Pine mountain, in Rabun county. *

CORUNDUM IN SOUTH CAROLINA.—Corundum is reported from Laurens, Anderson and Oconee counties, and I have seen specimens that were said to have been found in Pickens. The western portion of this State is in the line of peridotites as indicated by the direction of the belt in Georgia and North Carolina, and these rocks are known to exist along the border in the northwestern corner; but no work has been done to trace out their distribution nor to develop the corundum deposits, if such exist.

CORUNDUM IN NORTH CAROLINA.—As remarked above, this State presents the greastest development both of peridotite and corundum. The belt here attains its greatest width, and the largest

*A Preliminary Report on the Corundum deposits of Georgia, by Francis P. King, 1894 Bulletin No. 2 of the Geological Survey of Georgia.

outcrops of chrysolitic rocks in the Atlantic States are found in the southwestern counties. As indicated on the map, (plate I) corundum occurs in Clay, Macon, Jackson, Haywood, Transylvania, Buncombe, Madison, Yancey and Mitchell counties along the belt of basic magnesian rocks; and it is found east of the mountains in the counties of Cleveland, Burke, Gaston, Alexander, Iredell and Guilford. More particular mention is made of these localities under another head beyond.

CORUNDUM IN VIRGINIA.—Thus far I have been able to find corundum reported from only two localities in this State. The first is a large deep blue crystal found in Louisa county by Mr. Louis Zimmer, and reported by Mr. George F. Kunz.* The second is that described by Dr. Genth in 1890, and noted above in describing the mode of occurrence in gneiss. The peridotite belt is continued through the State by a great number of talc and serpentine rocks, but no corundum has been reported from any of these localities.

MARYLAND.—Although the peridotite belt is well represented in this State, no corundum localities are known.

CORUNDUM IN PENNSYLVANIA.—The serpentine belt that comes diagonally across Maryland, is continued through the counties of Lancaster, Chester, Delaware, Montgomery and Bucks. Corundum is found associated with it in many places, especially in Chester and Delaware counties, and, a few years ago, was mined to a certain extent in the former. It is found here in chloritic zones about the serpentine, but in larger amounts in granular albite, much like the occurrence in feldspar veins at Buck creek, in Clay county, North Carolina.

Zones of chloritic minerals along the borders of the serpentine masses and in the larger joints, are constantly present in these corundum localities, and chromite is found in the mass of the serpentine itself. Considerable prospecting has been done in Pennsylvania, and corundum has been mined in one or two places but these are now abandoned.

CORUNDUM IN NEW JERSEY.—The crystalline belt disappears

*George F. Kunz, Mineral Recources of the United States, 1883-4, page 736.

under the Jura-Trias near Trenton, almost immediately on crossing the Pennsylvania line. Portions of it outcrop again to the northward in the Highlands, but in the line of the peridotite belt, it does not reappear till we find it on the opposite side of the State at Hoboken, where serpentine is found, but no corundum.

Corundum is found, however, in Sussex county along the borders between the crystalline limestones and the gneiss.

CORUNDUM IN NEW YORK.—Corundum is also found with the white limestone of this State in Orange county. Emery, an intimate mixture of granular corundum and magnetite, is found east of Peekskill, in Weschester county, in basic magnesian rocks, which have been shown to be eruptive in origin.* This Emery is also often intimately intergrown with chlorite and green spinel, though there are no well defined chlorite zones such as are developed about the peridotites of North Carolina. This has been mined to a limited extent, though the product is said to have been too soft, and it is not worked now.

CORUNDUM IN CONNECTICUT.—Connecticut has thus far furnished only surface specimens of corundum, nothing of commercial importance. Early in the century, a mass of cyanite was found at Litchfield, "associated with talc, sulphuret of iron, and corundum . . . supposed to weigh 1500 pounds."† Dana also reports it from Norwich. Both of these localities are in regions of crystalline rocks.

CORUNDUM IN MASSACHUSETTS.—About thirty years ago, the emery vein at Chester was found in a chlorite schist zone lying between a talc rock on the east and a horneblende schist on the west. The vein traverses the mountains on both sides of Westfield river, in a nearly north and south direction, and has been traced for a distance of about four miles. A typical section from west to east would be about as follows: (*a.*) Horneblende schist, black, coarse crystalline, often feldspathic and banded, gneissic; (*b.*) Chloritic schist, bearing lenticular masses of emery and magnetite, sometimes becoming talcose, and often bearing radiating tourma-

*George H. Williams, American Journal of Science, 3, 1886, XXXI; pages 26 41; 1887, XXXIII, pages 135 144 and 191-199; 1888, XXXV, pages 438-448; 1888, XXXVI, pages 254 269.

†Edward Hitchcock, American Journal of Science, 1, VI, 1823, page 219.

line clusters. This belt is usually about twenty feet wide. (*c.*) Granular quartz in a vein one to two feet wide; sometimes entirely disappearing. (*d.*) Talc schist, sometimes chloritic and of fine texture, closely resembling serpentine; fifteen to twenty feet wide. (*e.*) Mica schist to the eastward.

The position of the emery in the chloritic zone (*b.*) is very variable, and it often lies along the border of this and the talcose rocks (*d*). The emery is associated with diaspore and margarite, especially about the edges of the lenticular masses. Grains of corundum are said to be found in the talc rocks sometimes. This locality is still worked, and is the only productive emery mine in the United States.

A few years after the discovery of emery at Chester, corundum was found in brown, scaly vermiculite associated with asbestos and other amphibole minerals in Pelham, Massachusetts. Professor B. K. Emerson informs me in a private letter that olivine rocks are also found here, and that the occurrence is very similar to the corundum localities of North Carolina. This locality has thus far proved of only mineralogic interest, however.

In the numerous serpentine localities of the State, no corundum has been found.

b. CORUNDUM IN NORTH CAROLINA.

We come now to a more detailed consideration of the corundum localities of North Carolina. In a general way, these are all indicated on the map (plate I), except those of Gaston and Guilford counties; and in the following enumeration of localities the peridotite belt will be considered first—beginning with the southwesterly corner of the State—and afterwards, the localities east of the mountains.

CORUNDUM IN CLAY COUNTY.—One mile south of Elf postoffice, on Shooting creek, and five miles southeast of Hayesville, peridotite occurs within about a mile of the Georgia line, and corundum is found associated with it in its most southerly outcrops, on the property of W. C. Ledford. It occurs here in "sand veins" in scaly vermiculites; and, a little further north, it occurs in feld-

spar veins and green chlorite, on the land of Samuel Hogsed. On the same place, it is found in feldspar, associated with zoisite, forming considerable masses; also in rounded nodules with rhombohedral parting (as in figures 1 and 3) highly developed, and covered with a very variable coating of white compact mineral (margarite?) which has undoubtedly been formed from the alteration of the corundum. Sometimes only small grains remain in the center of the nodules, while the coating has developed to great thickness.

About Elf, are found outcrops of the bright green amphibolite; and one place near the postoffice by the roadside, shows beautiful red corundum plates and grains, also having the rhombohedral parting. Sand corundum and the massive variety with feldspar were obtained in the Behr mine, at Elf. Corundum has been found on the surface and ploughed up in fields along the continuation of this peridotite strip up Lick Log branch almost to the gap between this and Tusquittah creek.

Except a few loose surface fragments near Shooting creek postoffice, no corundum has been found along the strip of dunite and talc that passes across the head-waters of Shooting creek, till it reaches the slopes of Chunky Gal mountain at Newton Penland's. From this point it has been found all the way up the mountain side to about half a mile east of the summit, where it narrows to very small dimensions and finally disappears. The occurrence in feldspar predominates toward the point of this outcrop, and this mode is found along with the sand veins and crystal corundum on the mountain side also. A decomposed amphibolite, bearing corundum disseminated through the mass in small grains, is now being extensively prospected near Penland's, and encouraging results are reported.

About three miles from Shooting creek postoffice, on Thumping creek, at Curtis Ledford's, is the corundum locality in gneiss described above under modes of occurrence (p. 61). Corundum is found here in rounded nodules in the gneiss and in veins of black mica; and is also developed in vermiculite beside one of the hypersthenite dikes. Some work has been done here, and portions of the rocks exposed are quite thickly studded with corundum.

At the head of Muskrat fork of Shooting creek, and about half way up the side of Chunky Gal mountain, corundum is found in garnet rock and brown scaly mica. This is also described above under the occurrence of corundum in gneiss (p. 61). This was being prospected at the time of my visit in the summer of 1894, and the work is said to have been resumed again this year (1895).

The only remaing deposit in Clay county is that with the great peridotite mass at Buck creek. The corundum mined here is found in veins of coarse feldspar and horneblende near the eastern edge of the peridotite. In fact, only a few feet of these rocks intervene between the corundum-bearing vein and the gneiss. Some corundum is also found in the vermiculite and chlorite that are developed through joints of the peridotite on the hillside west of the creek; and some is found here also in feldspar associated with zoisite and margarite. Portions of the bright green amphibolite at this locality are quite full of corundum; this is especially true of that on top of the mountain west of the creek, where the ground was covered with fragments of this rock; but many of these have been collected and hauled to Corundum Hill to be crushed and separated. The locations of the corundum workings at this place are represented on the map (plate III, page 34).

Corundum in Macon County.—I have visited and located on the map a great number of peridotite and soapstone outcrops in the valley of the Little Tennessee river above Franklin; but, so far as I was able to learn, corundum has been found at only one of those places. A number of them show considerable development of chlorite, and a little careful search in such places might be well rapaid. The locality referred to is at the head of Hickory Knoll creek, at an elevation of about 4000 feet, on the western slope of Fish Hawk mountain. A number of small dunite outcrops are found here, most of the blocks exposed near the surface having a well developed radial enstatite casing. Some corundum has been found in small encased nodules.

Six miles southeast of this, and just south of mount Scaly, corundum is found in small crystals and grains with outcrops of soapstone and a fibrous, asbestos-like mineral. Radiating casings

of talc here enclosing an ochreous earthy material doubtless represent the peridotite, which does not appear on the surface.

The next corundum region encountered lies seven miles east of Franklin, just north of the Cullasaja river, and included between its tributaries, Ellijay and Walnut creeks. On this, one of the most prominent western spurs of the Cowee mountains, are found more promising corundum localities than in any other region of equal area within the State, or indeed, in the whole Appalachian crystalline belt. At the southern point of this spur is Corundum Hill, the most widely known mine, and the one that has furnished by far the greater part of American corundum since the beginning of the industry. A map (plate IV,) and description of this place are given under the head of the distribution of peridotitite (p. 36), and a sketch of its history will be found beyond.

It is entirely unnecessary to add anything further here about the occurrence of corundum at this place. In this region, having a total area of less than twenty square miles, there are at least fifteen outcrops of peridotite; and corundum in greater or less quantity has been found associated with nearly all of them. Considerable prospecting has been and is now being done, and a great deal of capital has been invested there within the past three years.

Corundum has been found and some prospecting done in the gneiss on the summit of Turkey knob, on the Macon-Jackson county line, and fine specimems of red corundum are found in the gravels of Cowee creek. Well formed crystals are also found at Nona postoffice, seven miles west of Franklin, in the soil of gneiss.

Corundum in Jackson County.—Loose fragments and crystals of corundum have been found at Addie, on the ring of peridotite that lies northeast of Webster, (see (plate V, p. 38.) but prospecting has not yet located any important deposit in place. Good specmens of red corundum are found in gravel beds on the headwaters of Cullowhee creek.

On Caney Fork, two miles above its mouth, corundum is found in the chlorite schist in the manner described on page 57, on Mrs. Chastain's place and at Marion Long's. By digging a very shallow pit, a width of eight feet of this rock was exposed which was thickly studded with nodules of corundum. On Johns creek,

half a mile above its junction with Caney Fork, a chlorite schist outcrop occurs with a width of about a thousand feet. Corundum is said to be found in fragments over the surface, but no prospecting has been done.

At the mouth of Chastains creek, five miles up Caney Fork, corundum is found in the gneiss near the residence of W. W. Brown. It is in nodules one-half to one inch in diameter, and surrounded by a thin, compact casing. Two miles up Chastains creek, corundum is found in the same manner in the gneiss, near a belt of chlorite schist. At many points along Caney Fork, corundum is reported to be found in the fields and elsewhere over the surface. So far as I was able to learn, corundum has been found in only one place on West Fork, and that in association with a chlorite rock on Shoal Creek mountain, four miles north of Glenville.

South of Sapphire, corundum is found with peridotite on Snake ridge at several places; and on the lands of Dr. C. Grimshawe, near Montvale postoffice, in both Jackson and Transylvania counties.

At the Sapphire mines, corundum is found in similar associations in a great number of places on both sides of Horespasture river, and on the spurs of Great Hogback mountain. Several of these localities have been mined by the Sapphire Valley Company, and have yielded considerable quantities of corundum for the market. In a number of the outcrops, enstatite rock predominates, though more or less peridotite may be seen in nearly all of them. The mutual relations of these two rocks at some of the localities, as at the "Sapphire" mine, is such as to strongly point to the derivation of the enstatite from the olivine.

Besides a number of places that have been prospected, the following localities have been mined, to a greater or less extent, and constitute jointly the Sapphire mines. I am indebted to Mr. Charles N. Jenks, the superintendent, for the characterization of the product of the different workings.

The "Burnt Rock" mine is a mile and a half northeast of Great Hogback mountain, and produces nodular, massive corundum.

Some of the blocks taken out weighed as much as twenty-five pounds.

The "Brockton" mine is about a mile south of the Burnt Rock, and its product is a dull gray crystal corundum, which is easily separated from the vermiculite gangue.

The "Rattlesnake" mine is a mile and a half southwest of Great Hogback mountain and about the same distance northeast of Sapphire. Crystal and sand corundum are found here in chlorite and vermiculite about the borders of the enstatite rock.

The "Sapphire" mine is somewhat less than a mile northeast of Sapphire, and near where the Brevard road crosses Big Hogback creek. The product of this place is crystals and masses of white and gray corundum specked and mottled with blue.

The "Socrates" mine is half a mile south of Sapphire, on the north end of Bear Pen mountain. The corundum here is neither in crystals nor masses, but occurs in "shotty" nodules in the chlorite veins through enstatite rock. This furnishes the most perfect grain produced by these mines, and is well adapted to the manufacture of either cement or vitreous wheels.

The "Bad Creek" mine is on the west side of Bear Pen mountain and about half a mile from the Socrates mine. The corundum here is massive, and occurs with chlorite, margarite, garnet, biotite, feldspar, and a number of rarer minerals, forming a hard, tough vein. Mr. Jenks informs me that corundum constitutes about 35 per cent. of the whole mass, but that it is very difficult to separate it thoroughly from the gangue.

The "Whitewater" mine is about six miles southwest of Sapphire, on Whitewater river. The corundum occurs here in colored crystals, possessing some gem characteristics, and producing a good solid grain.

All of the localities enumerated lie near the Jackson-Transylvania county line, and the first three are situated in the latter county. A number of intermediate outcrops have been prospected a little, and still others yet remain untouched.

CORUNDUM IN TRANSYLVANIA COUNTY.—The Sapphire mines "Burnt Rock," "Brockton," and "Rattlesnake," described above, are located in this county, on the spurs of Great Hogback mountain.

Corundum is said also to be found with enstatite rocks in the same vicinity, on the headwaters of the Toxaway river.

On the West fork of the French Broad river, I saw corundum with similar rocks on the hill just west of the mouth of Owens creek. A number of shallow pits had been dug in prospecting, and large masses of margarite had been thrown out, bearing corundum and black tourmaline Asbestiform minerals are also found at the same locality.

A large number of similar outcrops are found to the eastward and northeastward, and corundum is said to occur with some of these on the North Fork of the French Broad river; but I was unable to verify these reports, owing to the profound air of secrecy maintained by the alleged discoverers.

Near the mouth of Owens creek, east of the corundum locality described above, a number of large boulders of disthene (cyanite) have been found on the surface, bearing grains and crystals of deep sapphire-blue corundum. The rocks at this locality are ordinary gneiss.

Corundum in Haywood County.—On Pigeon river, at Retreat postoffice, six miles southeast of Waynesville, corundum is found with cyanite and margarite in crystals scattered through the soil. The rocks are garnetiferous mica schist and gneisses, and no deposit has yet been found in place.

Three miles northeast of Canton, corundum has been found on the surface with an outcrop of dunite, but no workable deposit has been discovered. A mile north of this, at the "Presley mine," corundum occurs in pegmatite veins through dark green hornblende rock. The corundum occurs both in the mica and the feldspar of the pegmatite, and is sometimes wrapped in margarite. It often has the appearance of having altered into these minerals.

Just south of Newfound gap, red corundum is found on the surface about a small lenticular mass of dunite. It is also reported from a soapstone outcrop near the gap between Cabes and Crabtree creeks.

Corundum in Buncombe County.—Just south of the Carter mine, near the Madison county line, corundum is found about Democrat

with the long strip of peridotite which crosses Big Ivy river at this place. The Carter mine is in Madison, and very little prospecting has been done in Buncombe.

At Swannanoa gap, on the eastern border of the county, corundum is occasionally found in masses of cyanite.

CORUNDUM IN MADISON COUNTY.—The Carter mine is very near the Buncombe county line, in the eastern end of the county, and is situated on Holcombe branch, a tributary of Little Ivy river. It is at the north end of the strip of dunite which is continous from Morgan Hill, in Buncombe county. The corundum here occurs in a vein of chlorite and vermiculite which is developed at right angles to the lamination of the peridotite. It is in masses of white, pink, and blue colors, and is intergrown with greenish black, massive spinel and feldspar.

Recently, Mr. John A. Carter, of Democrat, has found a crystal of mottled blue and white corundum weighing 46 pounds. It is hexagonal in form, though rough and irregularly broken, and has the rhombohedral parting well developed. It was found loose above the Carter mine in a small stream very near its head, but search failed to discover its source.

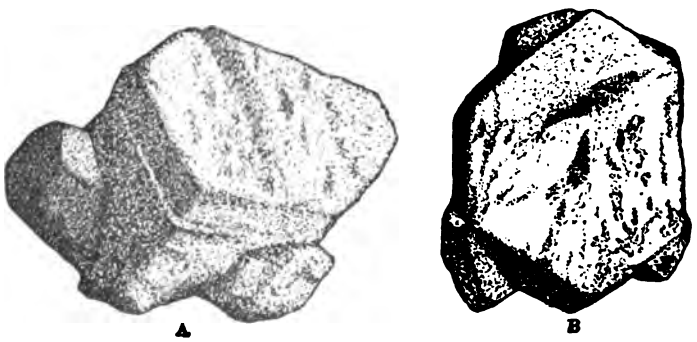

Fig. 7. Hexagonal crystal of corundum showing rhombohedral twinning. *A*, oblique view; *B*, end view; one-fourth natural size; weight 17 pounds. From an amphibolite outcrop half a mile north of the mouth of Ivy river, Madison county. (Specimen in possession of Mr. G. C. Haynie, Marshall, N. C. Figure drawn from photographs.)

The first corundum found in North Carolina was picked up from the surface three miles below Marshall, just above the mouth of Little Pine creek. A belt of soapstone and peridotite crosses

the river near this point, but the locality has never furnished a second specimen, so far as I was able to learn.

Three miles above Marshall and half a mile north of the mouth of Big Ivy river, corundum is found in large gray crystals on the surface of a large hornblende outcrop. One crystal from this place (figure 7), which weighs 17 pounds, and exhibits fine rhombohedrol twinning, is in possession of Mr. G. C. Haynie, of Marshall, the owner of the property.

CORUNDUM IN YANCEY COUNTY.—The principal corundum locality of this county is that known as the "Egypt (or Hayes) mine," ten miles west of Burnsville, on the western slopes of Sampson mountain. Corundum occurs in green chlorite along the borders of dunite and enstatite rock, the latter predominating. It is generally in distinct crystals, though granular massess are also found. The prevailing colors are white and banded or mottled blue and white. The corundum imbedded in dunite (figure 5), and the crystal shown in figure 3 are from this locality.

Eight miles southeast of Burnsville, on Celos Ridge, near South Toe river, corundum is found in crystals of two or three inches in diameter in the decomposed gneiss adjoining an outcrop of enstatite rock.

CORUNDUM IN MITCHELL COUNTY.—Three-fourths of a mile west of Bakersville, corundum crystals are found in the gneiss at William Bowman's. I also saw fragments of corundum on the surface and in the dump a mile and a half up White Oak creek from Bakersville, where work had been done for asbestos. The rock is a massive enstatite with fine radiating borders similar to those found about dunite in many places.

Since my visit to this region, Mr. D. A. Bowman, a local mineralogist, of Bakersville, writes me that "one mile due east from Bakersville, a massive blue corrundum occurs, with now and then a hair-brown piece." He further states that in the sumer of 1888 he obtained about 600 lbs. at this place, one piece of which weighed 23½ pounds. "Some small blue crystals found at this place would cut very nice gems were it not for cleavages."

No corundum has yet been found in North Carolina north of Bakersville.

CORUNDUM IN IREDELL AND ALEXANDER COUNTIES.—The country rock in these counties is ordinary gneiss, and surface specimens of corundum are found scattered over a large number of localities, especially in Iredell. Grayish masses are found several inches in diameter, and the smaller ones frequently have crystal form. All are more or less altered, and most of the specimens have a sheath of compact damourite or margarite, (figure 8) which is sometimes developed to such an extent that only a trace of the original corundum remains in the interior.

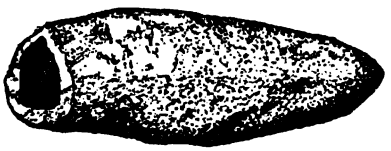

Fig. 8. A tapering crystal of black corundum enclosed in a sheath of compact margarite. One-half natural size. From Belts bridge, Iredell county. (Drawn from a photograph.)

In the alluvial deposits first worked by the Acme company at Statesville, blue and pink corundum was found in clays and sands, either in small loose pieces or in masses with cyanite. On passing through the clays and gravels, a massive hornblende rock was encountered, and a little search discovered a vein of feldspar bearing corundum and separated by vermiculite from the hornblende rock through which it passed. In its widest place, this feldspar-corundum vein had a thickness of two and a half feet, and was very rich in corundum.

The only other locality where corundum has been found in place in this region is eight miles northwest of Statesville, and just north of the Charlotte and Taylorsville railroad, on the Hunter place. Here no such alluvial deposits were encountered, and the amphibolite is of much finer texture than that at Statesville. But otherwise, the occurence is very much the same. The corundum is almost coal-black and is associated with feldspar and vermiculite in the joint system of the rocks, much in the same manner as that found in some of the dunite localities of the mountain region. The mode of occurrence is described and illustrated

(figure 6) on page 93. Near this place, large masses of corundum with margarite are found on the surface. The soil and decomposed rock are so deep over this region that very little can be determined about the form or extent of these amphibolites. Only occasionally does a stream or a wash in the hill side offer an exposure of rock that may be readily recognized.

CORUNDUM IN BURKE AND CLEVELAND COUNTIES.—I am indebted to Mr. H. B. C. Nitze for the following notes in regard to the occurrence of corundum along the borders of Burke and Cleveland counties, near the corner of Catawba. The rocks of the region are highly garnetiferous, gneissic, mica schist. Grayish blue, tapering corundum crystals are found on the surface along the ridge leading northwest of Carpenters knob. On the waters of the South Fork of the Catawba, in Burke county, corundum of a similar nature is found in "pockets" containing from one to two hundred pounds. Monazite is found in the placers of the streams. Dr. Genth mentions "crystals of corundum surrounded by fibrolite" from this locality.*

CORUNDUM IN GASTON COUNTY.—Corundum was discovered in this county at Crowders, Chubbs, and Kings mountains by Dr. C. L. Hunter, about forty years ago. It was found in masses and six-sided crystals "in place—associated with mica and quartz aggregate." Margarite was found with it; and, in places, by the gradual introduction of iron oxids, a transition to granular emery was observed. No large quantities have been found here, and thus far, the discovery has proved of only mineralogic interest.

CORUNDUM IN GUILFORD COUNTY.—In the titaniferous iron ore belt that traverses the northwest corner of Guilford county, Dr. Genth found true emery at the McChristian (or McCuiston) place, seven miles north of Friendship. One variety was reddish, granular, and had "much the appearance of a granular reddish brown garnet, for which it has been mistaken, until the analysis proved it to be not a silicate, mixed with granular magnetite, but *corundum*." Another, found in the same locality was grayish in color;

*Bulletin 74, U. S. Geological Survey, 1891. The Minerals of North Carolina, page 30.

and "the minute crystals of corudum have a yellowish or brownish white color, and show in many places cleavage fractures, which give it the appearance of a feldspathic mineral."*

The following analyses of these varities are given in the same place.

Analyses of Emery from the McChristian place, 7 miles north of Friendship, Guilford county.

	REDDISH BROWN.	GRAY.
Silica	1.39	0.98
Titanic acid	0.78	2.42
Magnetic iron oxid	42.77	46.29
Oxid of Manganese and Cobalt	1.00	1.27
Chromium oxid	0.30	trace
Alumina	52.24	44.86
Magnesia	0.68	3.27
Lime	0.84	0.91
	100.00	100.00

CORUNDUM IN OTHER LOCALITIES.—In the report of the North Carolina Geological Survey for 1875, large hexagonal crystals of corundum are reported from Forsyth county (page 299), and a reddish variety from Polk (Appendix page 65). Small particles are also said to occur in cyanite in Wilkes county; and Dr. Genth says that "rarely small remnants of corundum are found in the pyrophyllite slates of Chatham county." He also mentions the locality of Valley river in Cherokee county for corundum, and says that emery is found near Salem, Forsyth county.† I have not yet had an opportunity to verify these reports, but hope to do so before publishing a final report on this subject.

(6.) METHODS OF PROSPECTING FOR CORUNDUM.

The early discoveries of corundum in North Carolina were not the result of any systematic search; in fact, corundum, as it is now known in this State and Georgia, was not then a commer-

*Report of the Geological Survey of North Carolina, I., 1875, pages 245, 246.
†Bulletin 74, U. S. Geological Survey, 1891, pages 29-31, 96.

cial mineral, and nothing was known of its occurrence with peridotite. Accidental finding of surface fragments led to the discovery of extensive deposits; and the subsequent working of these and other localities has given to mineralogy and mining a great fund of information on this subject that is to a large extent entirely new. As usual in the case of things new, many mistakes were made in early prospecting and attempts at mining. Mistakes are made yet, and they will doubtless continue for some time to come, but many of the earlier errors need not be repeated if due regard is had to the store of information that has been accummulated by more than twenty years of experience.

Those who would search for corundum had best see, first of all, an actual corundum mine or a place where prospecting has been done and corundum found; and note carefully the conditions. In the southwestern portion of the State this may easily be done without great inconvenience. If the preceding pages have been read, or even a small portion of them, it will already be understood that conditions are rarely duplicated exactly, even in localities very near together. Certain types of rocks and minerals, however, may be observed in the greater number of them; and these may be profitably used as guides in searching for new localities. Of course the prospector must be able to recognize corundum itself in all of its common forms.

Loose fragments of corundum in the soil or stream beds are, of course, the surest "signs" of corundum deposits, though not always the most easily traced to their origin. The extreme resistance of the mineral to the ordinary process is of abrasion and decomposition render it almost indestructible when exposed on the surface. Hence, it may be transported for great distances down the mountain slopes and streams without showing any appreciable alteration and but little wear. When associated with fragments of peridotite, chlorite, or talc, the corundum is a much more valuable guide. In such cases, it has probably been transported only a short distance, and the search for the source becomes far less difficult. Where no corundum is found with

the rock fragments or minerals indicated, and none is found by panning the soil or sand, as in the ordinary search for gold, there is little encouragement to seek further.

The "indications" are followed up the grade by which they would most naturally have reached their present position. If in a stream bed, the search is made up the stream or its tributaries till fragments are no longer found, and then up the adjoining hillsides till the parent mass of peridotite is reached. The borders of this rock are first examined. If the border is not readily found by inspection, ditches are cut through the soil and decomposed surface materials at right angles to the strike of the country rock. The chlorite and vermiculite along the contact between the gneiss and peridotite should then be examined for corundum. A ditch, passing completely through the soil, should follow this contact zone; and, at intervals, shallow pits or cuts should be sunk to disclose the nature of the deposit. Where no encouraging development is found about the borders, it may be worth while to cut ditches across the peridotite mass for the examination of the joint zones; but these are usually less developed than those about the borders.

Margarite is found abundantly with corundum in some places, but in the majority of the North Carolina localities, this is not true, and its discovery usually follows, rather than procedes, that of the corundum. The emery mine at Chester, Massachusetts, however, was discovered by the finding of this mineral, and, when found, it is to be regarded as a good "indication."

Obviously, the points given above apply chiefly to corundum associated with peridotite. It is found, however, in a number of other associations in the State, and several of those in amphibolite and gneiss give promise of becoming of commercial importance. For these occurrences, there seems to be no important index, except to find the corundum itself. When it is developed in considerable quantity, there should be no difficulty in finding it in the soil and in the gravels of the adjacent streams.

In some cases, where chlorite and vermiculite are found abundantly on the surface, it may be advisable to trace them to their origin, even though corundum may not be found floating

in the soil with them. Corundum itself, however, is the only sure indication of new deposits, and other guides, though often of valuable assistance, should be regarded as pointing only to *probabilities.*

An ordinary wash-pan, or even a shovel, will serve very well in examining the gravels or soil; and any one may readily determine for himself whether corundum occurs in a given locality. By a little practice, all the heavy minerals in the soil or gravel may be shaken to the bottom of the pan and the lighter materials washed off over the edge. The heavy minerals will be found usually to contain grains of magnetite, garnets, dark hornblende, and corundum, if any is present.

Finally, however good the indications, even from the presence of corundum itself, no extravagant anticipation or large investments are justifiable till the deposit has been thoroughly explored by intelligent prospecting. Had this truth been borne in mind, trite as it may seem, much disappointment and financial loss would have been avoided and the mining reputation of the State saved many serious blows.

(7.) MINING AND CLEANING METHODS.

Twenty-five years ago, the corundum fields under consideration were entirely new to the mining world. Corundum itself, as a commercial article was scarcely known except in the forms of emery and the gems; as an associate of peridotite, it was not even known to mineralogy. There were no precedents in mining, and every step was evolved by the slow and expensive process of experiment. Undue excitement had been created by the finding of a few gems, and the idea that corundum might be profitably mined as an ordinary abrasive had scarcely been concieved.

Under these conditions, the first undertaking (at Corundum Hill) was naturally a failure. A hydraulic method with short sluice systems was adopted for working the corundum-bearing soil and gravels, and some of the chlorite zones were opened. Only the larger crystals and promising gem materials were saved.

With the exception of the gems, the product was sold for cabinet specimens and for the manufacture of dental appliances; but the work was soon found unprofitable. The concentrated gem-bearing gravels were exhausted, and the mine abandoned.

Two great mistakes were made in this early work; first, too much importance was attached to gem mining; and, second, the smaller fragments, or "sand-corundum," which afterward became the most important product, were allowed to waste. Prospecting, and some small attempts to mine in other localities during the next few years, soon demonstrated the scarcity of true gems. When Dr. H. S. Lucas reopened the work at Corundum Hill, it was purely for the purpose of mining corundum as an abrasive, and methods were adopted for saving the whole product of the mine. On this basis, the work has been successfully continued to the present time, not even closing down entirely during the panic of 1893 and 1894.

Mining Methods.—Naturally, the methods of work adopted in the few places that have really been mined, as distinguished from prospecting, have varied greatly, according to location, character of material, and other variable conditions. The area under consideration is located entirely in the mountainous and hilly districts of the western part of the State, and the outcrops are usually on high ground, with abundant natural drainage. These conditions and the nature of the border zones of chlorite and vermiculite, which are the principal deposits worked, have led to the adoption, in the majority of cases, of open cuts and drifts.

So long as the work is confined to the comparatively superficial portions of the deposit, the open cut is the most advantageous. But, with increase in depth, the jointed peridotite, with its great development of slippery magnesian minerals along the cracks, is exceedingly liable to fall in. Such cuts at Corundum Hill, at a depth of twenty to thirty feet, have loosened great masses, and have sometimes produced cracks in the surface at a considerable distance from the working. These are a continual menace to the miners; and, in a few cases, they have slipped into the cuts, though without more serious result than to stop the work.

The same trouble, though to a less degree, is sometimes experienced in drifts, and it is very difficult to timber the workings in such a manner as to be perfectly safe. Much of this trouble, however, is really due to unsystematic work and employment of unskilled men. After the work in open cuts had been rendered impracticable at Corundum Hill, the mining was continued by drifts. In one place, several of these have been driven, one above another, in the same vein.

In a few localities, small shafts have been sunk, but generally, this is done only where the configuration of the surface is not favorable to cuts and drifts. The expense of hoisting and pumping incurred in shafts is probably the chief objection to them.

The material handled, in the great majority of cases, is loose, scaly chlorite and vermiculite with corundum disseminated through it, and is easily removed with a pick and shovel. In solid feldspar veins, however, as in some of the Sapphire mines, and at Laurel Creek (Ga.) and Buck Creek, blasting has to be resorted to, and afterward the material crushed for cleaning. One of the drifts at Corundum Hill is now being cut through the gneiss wall adjoining the peridotite. It is very hard and thickly impregnated with corundum, and must, of course, be removed by blasting. In removing the material from the mines, hand cars and wheelbarrows are employed. It is then, according to its nature, dumped into wagons or sluice-troughs to be carried to the mill for cleaning.

Methods of Cleaning.—The prime object of all methods of cleaning corundum is, of course, the removal of all impurities as completely as possible; for any other mineral that is ever found in association with corundum, though it may be very hard itself, is always softer, and if left with it in considerable quantity, will appreciably reduce its abrasive power. But the mere removal of impurities is not the only point to be considered in devising methods of cleaning. This must be done with the least possible injury to the cutting power of the corundum grains. The sharp edges attained by crushing must not be ground off, and no large percentage of it should be lost by reducing it to "flour."

Owing to the high specific gravity of corundum, it can be effectually separated from most of its associated minerals by washing methods in many ways similar to those adopted in placer mining for gold. Where the corundum occurs loose in chlorite and vermiculite scales, little other treatment is necessary; but, when it is enclosed in a tough gange of feldspar, margarite, and other minerals, or is a constituent of a solid rock, as in the gneiss and some of the amphibolite occurrences, the minerals must be thoroughly broken apart before separation. For the accomplishment of this purpose, the abrasive power of the corundum itself is used, by scouring the crushed material together, so that the particles cut the softer minerals from each other. All cleaning methods, then, involve the three processes, crushing, scouring, and washing. The means by which these processes are applied may be best understood by descriptions of concrete cases.

Methods of cleaning Corundum at Sapphire.—I am indebted to Mr. Charles N. Jenks for the following outline of methods adopted by him at the Sapphire mines.

With crystal corundum, which is found in loose, scaly vermiculite, only the simplest treatment is necessary. It is placed in a box through which flows a strong current of water, and stirred vigorously with hoes. The scaly minerals float off with the current, leaving the corundum about 95 per cent. pure; and this requires only crushing and sifting into sizes to prepare it for the market.

But with every other variety of corundum, the separation of impurities is more difficult and the methods of treatment correspondingly more complicated. The material is first broken into coarse grains by passing through crushers and rolls. In this process, much of the adhering impurities is broken loose; and this may be partly removed by the gravity process described above; that is, by stirring in a strong current of water. It is then passed through a machine in which a coarse worm, like a screw-conveyer, is carried on a revolving shaft. In this the adhering minerals are cut away by the grinding of the corundum grains upon each other; after this it is again subjected to

the gravity treatment in a strong current of warter. The last process, and one by which the corundum is brought to a high degree of purity, is in a machine called the "muller", or "chaser". In this machine, two heavy wooden rollers move around the circumference of a shallow tub. The partially cleaned corundum is thrown into this tub, and is stirred constantly by iron teeth that move in front of the rollers. Being thus alternately stirred up by the teeth and pressed down by the rollers, a scouring motion is continually kept up between the grains, and the impurities are gradually cut away. In this action, the impurities are reduced to the form of a fine powder, and are carried away by a small current of water which continually flows through the tub. This process is continued from three to five hours, according to the difficulty of cleaning and the degree of purity required.

Methods of cleaning Corundum at Corundum Hill.—Two classes of material are produced by this mine; namely, the sand corundum (and crystals) contained in the vermiculite and chlorite developed along the borders and in the joints of the peridotite ; and the contact gneiss impregnated with corundum. Each of these requires its special mode of treatment.

Until recently, the sand corundum veins were the only deposits worked at this mine. All of the material of this class is sent from the mine to the mill, a distance of a mile and a half, in a small trough carrying a swift current of water. In this course, there are several vertical drops of five to ten feet to facilitate in breaking loose the scaly minerals adhering to and enveloping the corundum. At the mill, all material that will not pass through a screen of 14 mashes to the inch is crushed between rolls and passed, with the originally fine material, to the gravity boxes, or sluices, where it is vigorously stired in a strong current of water. It is then treated in mullers, as in the process described above.

The gneissic material comes from the minein hard, tough blocks, sometimes quite large, and is hauled to the mill on wagons. A very primitive method is adopted for breaking the large blocks into sizes suitable for the crushers. A fire is built over them till they are heated through, and then they are suddenly cooled by throwing on water. Fortunately, only a small part of the product

requires this treatment. It is then passed through crushers and coarse and fine rolls till it will all pass through meshes 14 to an inch. It is then subjected to a scouring action in the auger-like machine described above, and passed on to the gravity boxes. The final cleaning, as in the other case, is given by the mullers.

The method of drying in use at Corundum Hill is also worthy of notice. When the material is removed from the mullers, it is allowed to lie over night in a heap on an inclined floor. This material, still wet, is carried up in an elevator and dropped vertically through a distance of about twenty feet down the stack of a furnace. At the bottom of this, it strikes an inclined plane and slides down this for a few feet through the flames of a wood fire. By this time it is thoroughly dry, and is passed into a chamber beneath, whence it is removed with shovels and subjected to a final sifting. All material not fine enough to pass through a screen with 14 meshes to an inch is again passed through the rolls, and the entire cleaning process is repeated.

The corundum thus cleaned is shipped to the company's mills at Chester, Massachusetts, where it is further crushed and sorted into sizes for the market. The coarser numbers are also passed through magnetic separators for the removal of the magnetite.

7. HISTORICAL SKETCH OF CORUNDUM MINING IN AMERICA.

The following chronological outline of the principal discoveries and the developement of corundum mining in the eastern United States has been compiled from the sources enumerated in the bibliography at the end. In the main, these sources are considered reliable, and it is believed that the outline here presented indicates with tolerable accuracy, not only the origin of the corundum mining industry, but also the growth of our knowledge of corundum in many of its most important mineralogic and geologic relations.

Besides the enumerations of discoveries, I have given short

sketches of all the corundum mines, properly so called, in North Carolina.

(1.) DISCOVERIES AND EARLY DEVELOPMENTS.

So for as I have found in the literature on the subject, corundum was not known in America before 1819. In that year, Mr. John Dickson, a teacher, of Columbia, South Carolina, sent Prof. Silliman a lot of minerals which he had collected on a tour through the Carolinas. Among these was a regular, six-sided crystal of blue corundum three-fourths of an inch long and one inch in diameter, with parting and striae developed similar to the East Indian corundum. It was sent without label, and in reply to an inquiry as to its locality, Mr. Dickson writes: "I think it was Laurens district; at all events, it was picked up by my own hands, if not *in situ*, in a place .....which it could have reached only by one of the usual and natural accidents which displace minerals of all kinds..... I am sure it is American and Carolinian." [1]

In 1822, both Edward Hitchcock and Parker Cleaveland described the mass of cyanite found at Litchfield, "associated with talc sulfuret of iron, and corundum.....supposed to weigh 1500 pounds." The corundum was massive and in six-sided prisms, of a dark grayish blue color, and imbedded in the cyanite. Both of these authors attribute their information to Mr. John P. Brace. [2]

In April, 1827, at a meeting of the Lyceum of Natural History, New York, "Major Delafield.....exhibited crystals of Sapphire from Newton, Sussex county, New Jersey." [3] In 1832, Dr. Fowler described this locality, pointing out the geologic and mineralogic relations of the corundum. It is found along the border of crystalline limestone. [4]

According to Mr. W. W. Jefferis (as quoted by Mr. Joseph Willcox) John and Joel Bailey claim to have discovered corundum in the serpentine region of Chester county, Pennsylvania, about 1822 to 1825. Dr. Thomas Seal collected specimens at

[1]Am. Jour. Sci., 1, III., 1821, 4, 229, 230.
[2]Am. Jour. Sci., 1, VI., 1823, 219; Cleveland's "Mineralogy and Geology," Boston, 1822.
[3]Am. Jour. Sci., 1, XIII., 1828, 380.
[4]Am. Jour. Sci., 1, XXI., 1832, 319, 320.

Unionville about 1832, and Mr. Jefferis himself saw large lumps in the fields there in 1837 or 1838.[1] A ton of surface fragments and boulders was collected about 1839 and shipped to Liverpool. But the search for the source of this material was unsuccessful till 1873, when a large lenticular mass was found in place. This consisted chiefly of corundum and margarite and carried some fine specimens of diaspore.[2]

In a report on the Mineralogy of New York, in 1842, Lewis C. Beck mentions the occurrence of corundum in the white limestone near Amity, in Orange county.

The first discovery in North Carolina was a large detached block of dark blue, laminated corundum, found three miles below Marshall, in Madison county, in the spring of 1847. Gen. T. C. Clingman, after considerable search, found another piece in the same vicinity in 1848—about a year before the first discovery of emery in place in Asia Minor by Dr. J. L. Smith.[3]

In 1852, Mr. W. P. Blake described corundum from the new locality at Vernon, Sussex county, New Jersey.[4] In the spring of the same year, Dr. C. L. Hunter discovered corundum and emery in place in Gaston county, North Carolina.[5]

In 1864, the occurence of emery at Chester, Massachusetts, was predicted by Dr. C. T. Jackson from his discovery of margarite there—a mineral which Dr. J. L. Smith had just found characteristic of the emery deposits of Asia Minor. On September 6th of the same year, Dr. H. S. Lucas discovered the emery in what had before been considered only deposits of magnetic iron ore.[6] Two years later, distinct crystals of corundum were found in the same deposits.[7] This discovery of emery soon led to the establishment of active mining, the first of its kind in America. This mine is still worked, though it has not been operated continuously from the beginning.

In 1870, Mr. Hiram Crisp found the first corundum that attracted attention to the present mining regions of North Caro-

[1] 2d Geol. Sur. Penn., C4, 1883, 346-351.
[2] 2d Geol. Sur. Penn., B, 1875, 31-33.
[3] Bull. 74, U.S. Geol. Sur., 1891, 293-1.
[4] Am. Jour. Sci., 2, XIII., 1852, 116.
[5] Am. Jour. Sci., 2, XV., 1853, 376.
[6] The exact date was furnished me by Dr. Lucas in a private letter.
[7] Am. Jour. Sci., 2, XXXIX., 1865, 87-90; XLII., 1866, 421.

lina. This was found at what is now the Corundum Hill Mine—Mr. Crisp living there at the time. A specimen was sent to Professor Kerr, then State Geologist, for indentification, and considerable interest was aroused on the discovery that it was true corundum. In the same year, Mr. J. H. Adams found corundum in very similar relations at Pelham, Massachusetts.*

In 1870-71, considerable activity was displayed in the search for corundum in the dunite regions of the southwestern counties of North Carolina; and new localities were soon brought to light in Macon, Jackson, Buncombe, and Yancey counties. In 1871, Dr. Genth also discovered the emery of Guilford county.† About this time, Mr. Crisp and Dr. C. D. Smith began active work on the Corundum Hill property, and removed about a thousand pounds, part of which was sold to collectors for cabinet specimens. Some of the masses weighed as much as forty pounds.

In the fall of 1871, the property was bought by Col. C. W. Jenks, of St. Louis, Missouri, and Mr. E. B. Ward, of Detroit, Michigan; and mining was soon begun under the superintendence of Col. Jenks.

In reply to my inquiry about the discovery of corundum in Iredell county, Mr. J. A. D. Stephenson, of Statesville, writes me as follows: "The first corundum found in Iredell county was found by myself near where the Collins (Acme) mine is now located, either late in 1874 or early in 1875. It was a mass weighing probably two pounds. I also found a lot of pink fragments near by." It was soon discovered in loose masses and crystals in many parts of the county, and small amounts have been found in Alexander, the adjoining county to the west.

(2) NORTH CAROLINA CORUNDUM MINES.

Mining proper, as distinguished from prospecting, has thus far been restricted to a few localities in the counties of Clay, Macon, Jackson, Madison, and Iredell. Extensive prospecting, however, has been done at a number of places which have come to be known

*Am. Jour. Science, 2, XLIX., 1870, 271, 272.
†Rept. Geol. Sur. of N. C., I., 1875, 246.

locally as "mines;" and more or less work has been done at nearly all the localities where corundum is known to occur in the State. Most of this has been done in the most primitive and unsystematic manner. Little pits are dug here and there, no deeper than a man may conveniently throw the dirt from with a shovel; and trenches are dug, apparently at random, in every direction over the surface about the peridotite outcrops. At few of the corundum localities enumerated, has the work been sufficient or of such a nature as would reveal the extent and value of the deposit.

Much has been learned, however, by the experience of a quarter century; and the prospecting of recent date has been more intelligently directed and the results correspondingly more satisfactory. To find that a place has been prospected and abandoned, however, is still not to be regarded as conclusive evidence that it is worthless; and I have no doubt that the work now under way, and that of the future will, in many cases, prove the correctness of this statement.

Short historical sketches of the following mines are given below:

a. The Behr mine, Clay county.
b. The Buck creek (Cullakanee) mine, Clay county.
c. The Corundum Hill (Cullasaja) mine, Macon county.
d. The Sapphire (Hogback) mines, Jackson county,
e. The Carter mine, Madison county.
f. The Acme mine, Statesville, Iredell county.

In the preparation of these sketches, I have had to rely partly on such information as could be gathered piecemeal here and there through the country; but chiefly, and especially in regard to the more prominent mines, I am indebted to the kindness of superintendents and mine-owners for most of the facts presented here. I would mention especially Dr. H. S. Lucas, who first placed corundum mining on a successful basis, and who has been identified with the industry for twenty years; and Mr. Charles N. Jenks, superintendent of the Sapphire mines, who was associated with his father, Col. C. W. Jenks, in the first work of the kind undertaken on a commercial scale. Valuable information

has also been furnished by Mr. A. M. Stoner, of Franklin; and, in regard to recent developments and prospecting, I am much indebted to Mr. L. S. Ropes, of Franklin, and Dr. C. Grimshawe, of Montvale. Mr. J. A. D. Stephenson, of Statesville, Mr. John A. Carter, of Democrat, and Mr. U. S. Hayes, of Bald Creek, have furnished important data in regard to the operations in their respective localities.

a. THE BEHR MINE, CLAY COUNTY.

This mine is located five miles east of Haysville, at Elf post-office, on Shooting creek. It was opened in 1880 by Dr. H. S. Lucas. It was afterward bought by Herman Behr & Company, of New York, and was operated till 1890. A steam cleaning plant was erected at the mine, and considerable work was done. Much of this was doubtless of the nature of prospecting, but I am informed that several car loads of cleaned corundum were shipped. The location of the mine in a low place by a branch necessitated the constant use of pumps for drainage. The nearest railroad is about twenty-five miles distant.

b. THE BUCK CREEK (CULLAKANEE) MINE, CLAY COUNTY.

In the report of the North Carolina Geological Survey for 1875, Dr. C. D. Smith states that he was the first to find corundum at Buck creek. Large loose blocks with feldspar and black horneblende were found on the surface. The first prospecting was done by Maj. Bryson about 1875; and two years later Mr. Frank Meminger worked for about six months and removed about thirty tons of corundum.

For a period of ten years no further operations were undertaken; then work was resumed by Mr. Ernst and continued for nine months, chiefly in the nature of prospecting. During another period of four years, the mine was idle; then operations on a liberal scale were begun by Mr. Gregory Hart, and continued for a year and a half, during which time a shaft was sunk on the feldspar vein and several open cuts made on the chlorite zones about the eastern border of the peridotite. Considerable quantities of corundum were taken out during this time, but

nothing was shipped. Most of the product, however, was in large massive blocks with feldspar and black horneblende, and there was no economic method of crushing and cleaning it.

In 1893, the mine was purchased by the Hampden Emery and Corundum Company (as it is now styled), and the material already mined was hauled to Corundum Hill and cleaned with the product of that mine. Since that time a little prospecting has been done in the chlorite zones, but no further mining has been undertaken.

The nearest practicable shipping point is forty miles away, but by the construction of a few miles of wagon road, another station could be reached within twenty miles. (See also page 69.)

C. THE CORUNDUM HILL (CULLASAJA) MINE, MACON COUNTY.

This mine is seven miles southeast of Franklin, on Cullasaja, or Sugar Fork of the Little Tennessee river. The postoffice is Cullasaja. It is well known, not only for being the first worked, but also as the most successful corundum mine of the whole belt. Since 1878, it has afforded a constant annual product of 200 to 300 tons of cleaned corundum. During 1893-4, the output was not so large, but the mine was operated continuously during a period when nearly every industry of the country was paralyzed.

The beginning of operations here in 1871, by Col. C. W. Jenks, has already been noted in the sketch of "Discoveries and early developments" given above. This first mining was chiefly for gems; and the work was done by a hydraulic process with sluice boxes, very much in the same manner as the process is applied to gold mining. The surface soil and loose vein material were washed through a series of sluices, or rather boxes, inclined about thirty degrees. The material was constantly stirred so as to allow the lighter minerals to float off, while the corundum and other heavy minerals remained in the boxes. The concentrated corundum thus obtained was then removed and carefully searched for gems. Transparent and translucent fragments of ruby-red, sapphire-blue, yellow, green, colorless, and other shades were found. Some of these cut good gems; but, unfortunately, they were

always small and the quantity too limited to make the business profitable.

The value of the so-called sand corundum was not then realized; and the only material put on the market, besides gems and cabinet specimens, consisted of the larger crystals and lumps. About one hundred tons of this corundum were mined, and sold for dental and other purposes in this country and Europe. This material, however, possessed a degree of purity scarcely attained in the later product of any of the mines. The average force employed in this work was about twelve men.

In 1878, Dr. H. S. Lucas, of Chester, Massachusetts, bought the mine at Corundum Hill for the Hampden Emery Company, and began operations in October of the same year. Profiting by the experience of his predecessors, Dr. Lucas confined his operations to the mining of corundum for abrasive purposes only; and all corundum found—whether sand, crystals, or lumps—was saved and worked into sizes together. The abundant water-power of the Cullasaja was early utilized for the operation of washing and other cleaning machinery; and thus the business was placed on a basis which has continued successful to the present time.

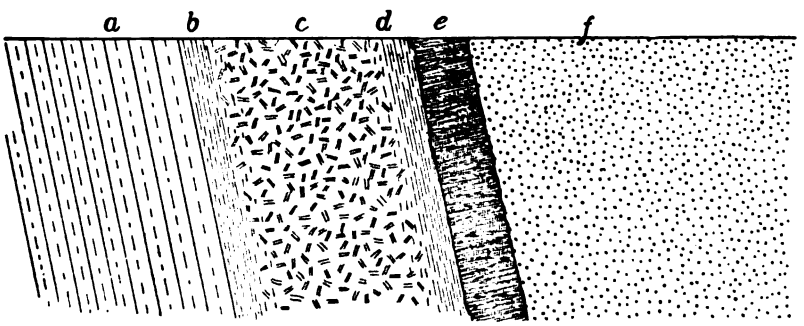

Fig. 6.—Diagramatic section across the corundum-bearing zone between gneiss and peridotite. Corundum Hill, Macon county. *a*. Gneiss, sometimes bearing corundum near the border; *b*, Schistose talc, chlorite, and vermiculite; *c*, Chlorite and vermiculite in interlocking crystalline plates with disseminated corundum; *d*, Similar to *b* but more talcose; *e*, Border of bladed and fibrous enstatite; *f*. Dunite. [For a description of the formations illustrated by this figure see page 55.]

A line of sluice troughs a mile and a half in length connects the mine with the mill, and the loose chloritic vein material is dumped into this as fast as mined. The rolling, falling, and

scouring action to which it is subjected over this course does much toward separating the corundum from the accompanying impurities, and it arrives at the mill in a condition which renders cleaning comparatively easy. (See fig. 6 [p. 93] and pp. 37 and 55.)

For two or three years, the "Hosea Moses mine" on Ellijay creek was worked by the same company, and, after a partial washing at the mine, the product hauled to Corundum Hill for cleaning. This was closed in 1894, and has not since been worked.

Recently Dr. Lucas has retired from the company, and the mines are under the management of the new president, Mr. Frank E. Bidwell. The force employed in the company's North Carolina mines has been somewhat variable, but it is usually about thirty or forty. The company (now styled the Hampden Emery and Corundum Company) also owns the Buck creek mine, but has not yet attempted to work it; also the Pine Mountain mine, (Laurel creek,) in Rabun county, Georgia, which was operated from 1880 till the spring of 1893; and the emery mine at Chester, Massachusetts, which is still in operation.

d. THE SAPPHIRE (HOGBACK) MINES, JACKSON COUNTY.

Corundum was known in the vicinity of Great Hogback mountain in the southeastern corner of Jackson county at the time when Dr. Smith wrote his report on this region, 1875.* He speaks of several hundred pounds having been taken out by digging small pits.

Work was begun here by the Sapphire Valley Mining Company in 1892, at the "Burnt Rock" mine, seven miles northeast of Sapphire; and shortly afterwards a number of places in the surrounding country were opened. A complete cleaning and crushing plant was erected on Horsepasture river, and considerable expense was incurred in building roads, bridges, stores and other houses, saw-mills, shops, etc. About fifty or sixty men were constantly employed in mining, prospecting, and improvements, during the year in which the mine was operated. Mr. Charles N. Jenks, the superintendent, reports a product of over 400 tons, one-fourth of which was crystal corundum 90 per cent. pure. Work was sus-

*Rept. Geol. Sur. N. C., 1, 1875, Appendix 91-97.

pended during the financial crisis of 1893, and has not yet been resumed. The new railroad to Brevard will affect a considerable saving in transportation, as the product was formerly hauled on wagons to Hendersonville for shipment, a distance of some forty miles. (For descriptions of the various workings, see pages 71 and 72.)

e. THE CARTER MINE MADISON COUNTY.

This mine is in the eastern corner of the county, near Democrat postoffice, in Buncombe county. It is located on Holcombe branch, a tributary to Ivy river, and marks the northern extremity of the belt of dunite which extends over a distance of more than two miles, with an average width of about one-fourth of a mile. Dr. C. D. Smith first found corundum here about fifteen or twenty years ago.

The first work was done by Mr. William Carter and Dr. H. S. Lucas, who took out a few tons in prospecting. Afterward work of a similar nature was done by Mr. M. E. Carter, and by Messrs. Rice and Coleman, who sold the property to Tarr, Hamilton and Company, of New York. This company began regular mining about 1886. A steam crushing and sizing plant was erected on the grounds, and about twenty tons of corundum were cleaned and shipped from Marshall. The work continued only about six months, and has not since been resumed. (See also page 74.)

f. THE ACME MINE, STATESVILLE, IREDELL COUNTY.

This mine is located about three-fourths of a mile west of the town of Statesville, and half a mile south of the Charlotte and Taylorsville Railroad. About 1875, Mr. J. A. D. Stevenson found corundum near the site of the present operations. The Acme Corundum and Mining Company began work here in February 1893 under the management of Mr. H. A. Collins. Some corundum was shipped in the form of large rough blocks and crystals, just as it came from the mine; but this was soon found unprofitable, and a steam mill was erected in March of the same year for cleaning and crushing. The product of cleaned material in 1893 was about fifty tons.

Considerable difficulty was encountered on account of the great

depth of soil and decayed rock. The mine is situated in a depression near the head of a small branch, where the alluvial deposits of clay are about fifteen feet deep. This material and the soft rock underlying it are so thoroughly saturated with water that great difficulty was experienced in holding them back out of the workings.

Mining was resumed in December, 1894, and since then, the work has been of the nature of prospecting for the purpose of locating veins under more favorable conditions.

The mode of occurrence of this corundum and that of the Hunter place, in Iredell, are described under the head of corundum in amphibolite, pages 58 and 59. See also page 76.

8. OTHER ECONOMIC MINERALS OF THE CORUNDUM BELT.

Incidentally the chromic iron and asbestos deposits were noted in passing over the region on the corundum work. These minerals have been found in promising abundance in many places, and hence a word in regard to them is appended here. While the corundum shows a great falling off northward, this is by no means true of the characteristic accompaniments of peridotite—chromite, asbestos, and nickel silicates.

(1) CHROMITE, OR CHROMIC IRON.

This mineral has been found in considerable abundance in Jackson county, near Webster; in Buncombe county, at Morgan Hill; and in several localities in Yancey, Mitchell, and Watauga counties. For analyses and more definite information, the reader is referred to Bulletin No. 1 of the present Survey, Iron Ores of North Carolina, by H. B. C. Nitze, 1893, pages 212-215.

(2) ASBESTOS.

A fibrous mineral which is called by this name has been the object of considerable interest in Jackson county, in the vicinity of Glenville; in Mitchell county, near Bakersville, and near the mouth of Squirrel creek on north Toe river; in Watauga county,

along the western slopes of Rich mountain; in Ashe county, on Elk creek; and it is found with all the enstatite rocks of the northeastern portion of this belt. Fibre of good length, color, and fineness has been found in many places; and the mineral is of sufficient importance to warrant further investigation. In some places this fibrous mineral is enstatite, while in others it is chrysotile, or fibrous serpentine. In a few cases it is possibly amphibole, the true asbestos.

(3) NICKEL-BEARING MINERALS.

Minute quantities of nickel are often present in the olivine rocks of this belt, but its presence can scarcely be detected in the fresh specimen except by chemical methods. But when the olivine begins to decompose under the influence of the atmospheric agencies, it is readily seen in the characteristic green silicates that are developed along the joints and fissures. Genthite, garnierite, and perhaps other nickel silicates are formed in such relations in the dunite at Webster, in Jackson county. These minerals have attracted considerable attention, and some prospecting has been done, but nothing of importance as an ore has yet been found.

Similar indications of the presence of nickel were observed south of Shooting creek, near Elf, Clay county, and south of Democrat, in Buncombe county. Small amounts of nickel staining have been seen in many places, showing a wide distribution of the metal in our olivine rocks; but no other localities were found that are considered worthy of special mention.

(4) SERPENTINE.

Mention has already been made (page 31) of the adaptation of the serpentines of this belt to architectural purposes. They are indentical in every respect with those of Maryland and Pennsylvania, which are largely quarried, especially in the latter state, for both interior decorative work and ordinary building purposes. The dark green and mottled varieties take a fine polish and give very rich effects for ornamental work where not exposed to wear or weather. The peculiar, but not unpleasing effect of the

lighter colors for general building purposes may be seen in many structures in Philadelphia, Baltimore, and Washington.

Outcrops of serpentine well suited to both these uses occur abundantly between Weaverville and Leicester, in Buncombe county, in the strip that crosses the French Broad river a mile above Alexander. Other masses equally as large are found on the Paint Fork of Ivy river, in Madison county, and on the waters of Bald creek, in Yancey county; but these are not so conveniently located for transportation.

There seems to be no reason why the Buncombe county serpentine should not come into the market in the near future. The era of substantial building has only just begun in the southern states, and as we learn to build, we should also learn to appreciate and appropriate our own resources.

9. LITERATURE ON THE CORUNDUM BELT.

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EXPLANATION OF PLATE VI.

PHOTOMICROGRAPHS OF THIN SECTIONS OF DUNITE.

Photographed with Feuss' objective No. 0. *Magnified* 12 *diameters.*

FIGURE 1.—RAILROAD CUT 2 M. WEST OF BALSAM GAP, JACKSON COUNTY.

This is an exceptionally fresh specimen of the pure olivine type. The perfectly crystalline, even grained texture of the rock, and the generally irregular (hypidiomorphic) structure are well shown; though crystal outlines, like that on the upper left hand side, are frequently seen.

FIGURE 2.—CARTER CORUNDUM MINE, MADISON COUNTY.

This figure represents the prevailing character of the surface exposure of dunite. These first narrow bands of yellowish green serpentine formed about the borders of the olivine grains are minutely fibrous, with the fibres at right angles to the boundaries of the olivine. They look very much like mortar in rubble masonry.

FIGURE 3.—CARTER CORUNDUM MINE, MADISON COUNTY.

This section shows a common type of fine grained olivine rock as seen between crossed nicols (polarized light). The minute grains are found to extinguish together over considerable areas, showing that the fine texture is the result of irregular cracking up of large grains similar to those shown in figure 1.

FIGURE 4.—WEBSTER, JACKSON COUNTY.

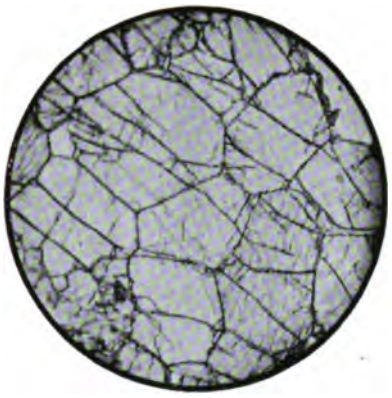
This specimen shows an advanced stage in the alteration of olivine to serpentine, the beginning of which was seen in figure 2. In the process of alteration, a considerable proportion of magnetite has been formed and deposited in dark bands about the olivine remnants, which appear white in the figure.

FIGURE 5.—PAINT FORK OF IVY RIVER, MADISON COUNTY.

Here we have the final result of the process of serpentinization represented in figures 2 and 4. No trace of unaltered olivine remains. The positions of the last fragments to disappear are marked by black accumulations of magnetite; otherwise the serpentine appears quite homogeneous in ordinary light.

FIGURE 6.—SAME AS FIGURE 5.

The subject of this figure is identical with the last, except that the section is here viewed between crossed nicols. The network of light bands ("mesh-structure") represents the first serpentine formed in the alteration of olivine, as shown in figure 2, and marks the boundaries of the original grains. (This figure is inverted with reference to figure 5.)



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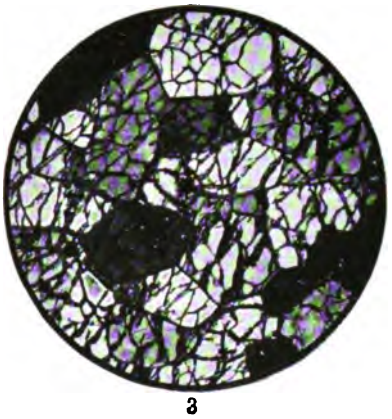

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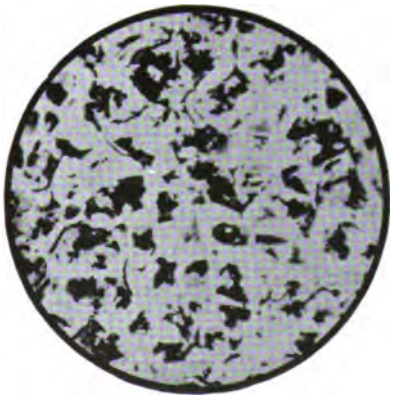

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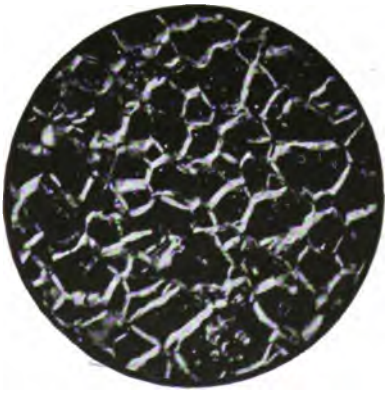

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THIN SECTIONS OF DUNITE. (MAGNIFIED 12 DIAMETERS).

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NORTH CAROLINA GEOLOGICAL AND
ECONOMIC SURVEY

JOSEPH HYDE PRATT, STATE GEOLOGIST

BULLETIN NO. 12

HISTORY OF THE GEMS FOUND IN NORTH CAROLINA

BY

GEORGE FREDERICK KUNZ, PH.D.

RALEIGH
E. M. UZZELL & CO., PUBLIC PRINTERS AND BINDERS
1909

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LETTER OF TRANSMITTAL

CHAPEL HILL, N. C., November 15, 1906.

To His Excellency, HON. R. B. GLENN,

Governor of North Carolina.

Sir.—I have the honor to submit for publication as Bulletin No. 12 of the Geological and Economic Survey, the report of Dr. George Frederick Kunz on the History of the Gems found in North Carolina.

Yours obediently,

JOSEPH HYDE PRATT,

State Geologist.

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PREFACE

The preparation of the report on the History of the Gems Found in North Carolina was turned over to Dr. George Frederick Kunz of New York as the recognized authority on gems. He has had access to all the information relating to gems and gem minerals on file in the office of the Survey, and has also drawn freely from the various publications by himself and others relating to the gems of the State. In his introduction, Dr. Kunz calls attention to the fact that the production of gems in the State has been largely incidental to the mining and production of some other mineral and that there have been but few localities that have been developed solely for gems. At the present time, however, there are several companies operating in North Carolina simply for gem minerals, the two more important companies being the United States Ruby Company and the American Gem and Pearl Company.

The report is freely illustrated and many of the colored illustrations are of gems in the Morgan-Tiffany and Morgan-Bement collections at the American Museum of Natural History of New York City.

Chapter I gives a brief historical sketch of gem mining in the State, but detailed accounts are given in many instances under the head of the individual mineral.

The various gem minerals are described in the next five chapters. The localities are also given and reference is made to the commercial value of the gem material found.

This report does not pretend to take up a detailed account of the geological occurrences of the gem minerals, or a study of their chemical and physical characteristics, as these will be discussed in a later publication. It has been published especially for distribution at the Jamestown Exposition.

JOSEPH HYDE PRATT,
State Geologist.

INTRODUCTION

North Carolina, with its magnificent mountains and its swiftly running rivers and streams, has now for some years come to possess almost as great a charm for the Northern as it long before had for the Southern tourist. "The land of the Sky" has become a favorite resort for the traveler, the invalid, the sportsman, the lover of nature, and the seeker for rest, from almost every part of the country. For the mineralogist, too, it has peculiar interest, so great, indeed, that its scenic attractions have, for such as he, been almost overmatched, not to say overlooked, in the search for the beautiful crystals that are found in its mountains, and the variety of rare, minute, and interesting minerals that occur in the brooks and streams associated with gold. Among these crystals and sands occur many minerals that have yielded true gems, and North Carolina has hence become one of the most *notable* States for gem production in the American Union.

The finding of these minerals, however, has been in most cases a secondary or incidental result in the search for and mining of substances more immediately desired for practical use on a larger scale. These last have been essentially three, which have developed in succession, and mark several stages in the mineral production of North Carolina.

These stages were: (I) The gold-mining, from early in the last century to the time of the Civil War; (II) the corundum and mica industry, for the quarter-century following that great struggle; and (III) the development of the "rare earths," and the monazite sands, in connection with recent scientific discoveries and appliances, within the last 10 or 15 years. To these may be added a fourth stage, viz., that of systematic mining for the gems themselves at various times, such as for sapphire at Corundum Hill; for ruby and rhodolite in the Cowee Valley; for beryls in Mitchell County, and later, for amethyst at Tessentee Creek, Macon County.

Through the gold belt of the western Carolinas and Georgia, that metal occurs widely distributed, but in very variable amounts. At certain points mining has been conducted with profit, and in some instances nuggets of impressive size have been obtained. More or less active working has long been done in the North Carolina gold fields, and the

total product has been very considerable; but, strange as it may seem, many of the discarded gold-washings of a century ago are now yielding more to the owner of the land for the obscure and long unknown monazite sands than for the gold originally obtained with them. In regard to this latest development, extended mining has recently shown that the hillsides, from which the monazite sands in the "branches" and streams originally came, contain an endless store of these rare minerals, and that when the ancient brook-washings are exhausted, the hillsides can be resorted to for a century to come. It is in the search for this mineral that most of the small and beautiful garnets, rutiles, sapphires, epidotes, and other gems have lately been found.

Between the gold-mining of earlier times and the more recent and varied developments, came the terrible years of the "war between the States." When that was past, brave and patriotic men like the late Gen. Thomas L. Clingman, afterwards United States Senator, turned their attention to developing the natural resources of their State and retrieving in every way possible the ruin and devastation that had swept over the South. Then commenced a period of exploration and discovery in the mineral and gem treasures of North Carolina that has progressed and expanded to a wonderful extent. It began with the corundum industry and the mica mines. The presence of the former mineral had been known for some years before the war, but it had not been developed. The first notice of its occurrence in the State was in 1846, by Prof. C. D. Smith, but with no particulars as to the locality. About 1850 General Clingman announced it from Madison County; and in 1852, Prof. R. T. Brumby, of the College of South Carolina, collected and labelled specimens from Clubb Mountain, in Lincoln County, and placed them in the College cabinet at Columbia, S. C. In the next year Professor Ebenezer Emmons, of the University of North Carolina, in a report on the midland counties of the State, mentioned a discovery of corundum by Dr. C. L. Hunter, in Gastón County. Little or nothing was done in regard to it, however, until immediately after the war, in 1865, when the Rev. C. D. Smith, of Franklin, Macon County, who had been an assistant to Prof. Ebenezer Emmons on the Geological Survey of the State, identified specimens that were brought to him, visited the spot whence they came, and discovered a number of important localities. In the next 5 years a great amount of exploration was done, mines were opened, and an important and enduring industry was called into being. Among those most active in this field of study and progress, besides Mr. Smith and General Clingman, were the able State Geologist, Prof. Washington C. Kerr, the enthusiastic and indefatigable collector, Mr. J. Adlai D. Stephenson, of Statesville, and

Mr. C. W. Jenks, who opened the Corundum Hill mine, at Franklin, N. C., about 1870, and was the first to find gem sapphire in its original matrix. During the same period, numerous valuable scientific reports and analyses were prepared and published by such authorities as Prof. F. A. Genth, Dr. J. Lawrence Smith, and Dr. T. M. Chatard; and the North Carolina corundum, its history, mineralogy, and composition, was thus made widely known.

Although the main value of the mineral as mined was for use as an abrasive material, yet pieces were obtained that had color and transparency enough to rank them in some cases as true gems and largely as valuable specimens. Among the first fine crystals were some obtained by Prof. C. U. Shepard; one of these, now in the Shepard collection at Amherst College, Mass., weighs over 300 pounds. Besides the collecting tours of Professor Shepard, many annual visits were made to the corundum region by Mr. Norman Spang, of Pittsburg, Pa., a wealthy and noted collector, who encouraged exploration, and brought back with him much of the choicest of the "treasure trove." Mr. W. E. Hidden, of New York, devoted a large part of 20 years to energetic and intelligent search for minerals and gems with wonderful success; and recently the State Geologist, Dr. Joseph H. Pratt, and Prof. J. V. Lewis have given extended and detailed study to the whole subject of the various occurrences of corundum in the State. All this activity has not only developed the industry itself, but has led incidentally to other discoveries. It may be, indeed, that more has been spent in the search and in attempts at mining, not always judicious, than the product itself has yielded; but the effect on the development of the State has been immense. In the matter of gems and remarkable specimens, these years of exploration have successively brought to light one and another fine gem, crystal, or rare mineral, to such an extent that to-day, were the North Carolina specimens removed from the great collections of the world, a gap would be left that could not be filled, in such places as the American Museum of Natural History, New York, the British Museum of London, the Imperial Museum of Vienna, the U. S. National Museum at Washington, the Field Columbian Museum of Chicago, the Musée de Historie Naturelle, Paris; and many others, important but less famous.

During the same general period, the mining of mica came to be another important industry in the revival of the State, and this also led to discoveries of other rare minerals in the search for valuable localities for mica. One of the most curious and interesting facts brought to light in this connection, was the clear evidence that some of the best mica mines had been long and extensively worked by ancient aborigines, either Indians

or earlier "mound-builders" (if these indeed be distinct peoples), or both. Ornaments cut from mica, as also shells and quartz crystals, are not uncommon in the burial-mounds of the Mississippi valley; and, as no mica occurs in that part of the country, it is clear that the old excavations, rudely made with stone tools, along the outcrops of large mica veins in North Carolina, were the source of this material, which was evidently prized by the prehistoric tribes and widely distributed among them.

It is a "far cry" from prehistoric mounds and ancient and long-forgotten mica mines to the incandescent lighting of our present civilization and the properties of rare chemical elements. But such are some of the contrasts that present themselves in speaking of North Carolina minerals. It is now some 18 years since the introduction of the Welsbach incandescent burner, or rather mantle, that has so improved our gas illumination. Instead of using the light produced by white hot carbon particles, as in ordinary flame, a hood or mantle is employed, which, when heated by the burning gas, glows with far greater intensity. This mantle consists of a loosely woven fabric impregnated with certain compounds of rare elements. The first forms of it employed zirconia salts; and this fact led to active mining of the small, opaque, and previously unimportant zircon crystals that are abundant at several points in North Carolina. Since then it has been found that even greater brilliancy is obtained by the use of nitrate of thorium. This latter is a rare metal, found in very few minerals and in small amounts; but it is notably present in monazite, a phosphate of this and other oxides of rare elements. Monazite was formerly regarded as a very uncommon mineral, but it has been found to occur quite abundantly in the sands of the stream-beds in the South Mountain region, comprising several counties of North Carolina, being derived from the disintegration of the country rock. Thus the monazite industry has now become highly important, and it is likely to continue and increase; as the demand for thorium salts for incandescent burners is very great. This latest stage of North Carolina mining—the search for the "rare earths," so-called—has developed extensively within a few years; though General Clingman was active in the earlier stages of it, in promoting the zircon mining, and Mr. W. E. Hidden first brought into use the monazite sands, and induced the Welsbach Company to experiment with them in 1884. In 1901 the monazite output of North Carolina was 748,000 pounds, valued at some $50,000. Only Brazil surpasses, or even approaches, this production. In 1906 the output was 697,275 pounds, valued at $125,510. A total of 8,426,004 pounds valued at $635,568, was mined in the 14 years 1893 to 1906, inclusive.

With these general historical outlines in mind, we may pass to a more

special account of North Carolina gems, that have been found, as above noted, chiefly as incidents in the course of mining enterprises.

The diamonds of North Carolina, although small in size and few in number, are undoubtedly authentic. The localities have been visited and the discoveries verified by good mineralogists. Whether their occurrence will always be as sporadic as these, or whether others will be found, time only can tell. Rubies, as fine in color as those of Burma, but generally small or containing imperfections, have lately been found in the Cowee Valley, in Macon County; considerable mining for them has been done, but the financial outcome is still somewhat problematical. Emeralds, remarkable as crystals, but rarely transparent enough for gems, were obtained in Alexander County, some years ago; but a greater quantity has been sold from the more recent Crabtree Mountain discovery, in Mitchell County, where the emerald is translucent to transparent, in a white granitic rock, and the whole is cut together as a matrix material—the quartz and feldspar contrasting charmingly with the emerald green. Aquamarines, which for beauty of colors have never been rivalled in any country of the world, have been found in some profusion, and many gems have been cut weighing from 1 to 30 carats, of the most beautiful sea-blue color. Beryls, both sea-green and yellow, than which none richer have ever been found, are also obtained in Mitchell County and elsewhere. Mention should also be made of the peculiar "lithia emerald," or hiddenite, found with the large emerald crystals above noted, at Stony Point, Alexander County. This gem-stone was discovered in 1879 by J. Adlai D. Stephenson, then sent by William E. Hidden to Dr. J. Lawrence Smith of Louisville, who named it *hiddenite*. The garnets of the gold washings are well known; but it remained for the Cowee Valley to produce a new variety of garnet which has received a distinct name, *rhodolite*, and has brought of late greater financial returns, probably, than any other North Carolina gem. The amethysts from various localities equal those found in any country of the globe; while smoky quartz, wonderful as crystals, that have commanded the attention and study of some of the greatest living crystallographers, has been obtained in Alexander and adjoining counties. These specimens have frequently been fine enough to cut into gems. But quartz in its choicest form,—rock crystal—has been found in Ashe County in such magnificent masses that one of the finest art objects shown at the Paris Exposition of 1900, was made from rock crystal obtained in this county in 1888 by the author as was the cover of the "Adams gold vase" presented to the same museum. These now form parts of the Matthiessen gift and Edward D. Adams gift to the Metropolitan Museum of Art, in New York, where they are two of the finest objects in the entire museum.

It is intended in this report to illustrate some of the principal North Carolina gems, more remarkable usually as crystals than as precious stones for jewelry, that grace the great collections before alluded to. All those shown on the colored plates, and many of the others, are contained especially in the Morgan-Tiffany collections, presented by the munificence of Mr. J. Pierpont Morgan to the American Museum of Natural History, at New York; these comprise the splendid collections formed by the author for Tiffany & Company, of New York, of American gems and precious stones shown at the Paris Exposition of 1889, and the still finer and more extensive one displayed by them at the Paris Exposition of 1900; also the Tiffany collection shown at the Cotton States Exposition at Atlanta, in 1894, and presented to the U. S. National Museum by Prof. L. T. Chamberlin.

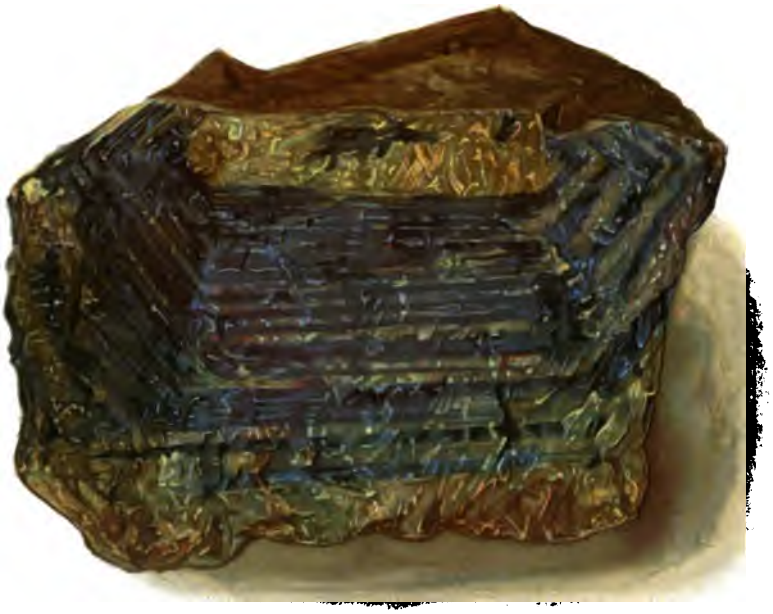
Many of the figures are loaned by the courtesy of the publishers of "Gems and Precious Stones of North America," and will form part of the new edition of that work, treating of the Morgan-Tiffany and Morgan-Bement collections of minerals in the American Museum of Natural History; this latter made up of the Spang collection and many from the Hidden, Wilcox, and other collections. It was thought well to illustrate for this report specimens in places which are readily accessible, and no collection on this continent contains so many choice examples of North Carolina gems as does this one.

Fuller discussions upon all these subjects, with geological, mineralogical, chemical, or crystallographic details, may be found in the reports issued by the North Carolina Geological Survey, which contains many most valuable papers and monographs by such authorities as Kerr, Shepard, Genth, Chatard, Hidden, Lewis, and Pratt, and in the Journal of the Elisha Mitchell Scientific Society, published at Chapel Hill; also in the Annual Reports of the Department of Mining Statistics of the United States Geological Survey, prepared by the author under the directorship first of Albert Williams, Jr., and then of Dr. David T. Day, who has done everything to encourage and increase public interest in the development of the precious stone and mineral resources of the United States. Many papers have likewise appeared on the same topics in the American Journal of Science. Among all these, much of the literature of the gem product of the State may be found. It is the purpose of the present report to present in a clear and concise manner such facts as may interest the mineralogist, the collector, or even the tourist who wishes to acquaint himself with these "crystallized flowers," as the celebrated Abbe Hauy called them, whose enduring beauty remains unchanged by the variations of climate found upon our globe.

The mineral collections in the State Museum at Raleigh include a number of valuable and interesting collections of gems and gem minerals prominent among which is that of Mr. J. A. D. Stephenson, for more than 30 years a resident of North Carolina and an enthusiastic explorer of its natural resources.

Much credit is also due to the late James D. Yerrington, for many years the agent of the Henry D. Morse Diamond-Cutting Company, who for 30 years carried on correspondence with North Carolina, doing much by his kindly advice and care to encourage the people to send small gems, which in many cases led to valuable results.

GEORGE FREDERICK KUNZ.



A

Section of a sapphire crystal,
banded blue and yellow, Jenks Mine, Macon County,
North Carolina.

B

Asteriated sapphire.
Jackson County,
North Carolina

C

Ruby,
Jenks Mine, Macon County
North Carolina

First sapphire found in matrix
Corundum Hill, Macon County,
North Carolina.
Restored to matrix after being cut

E

Sapphire (Brown
Chatoyant,
McDowell County,
North Carolina

F

Ruby,
Cowee Valley,
Macon County, North Carolina

G

Ruby,
Cowee Valley,
Macon County, North Carolina

E No 1

HISTORY OF THE GEMS FOUND IN NORTH CAROLINA.

By George Frederick Kunz, Ph. D.

CHAPTER I.

HISTORICAL SKETCH OF GEM MINING.

Gem mining in North Carolina had its origin; first, in the finding of rolled crystals in the gold washings in several counties, some of them of gem value, notably a few diamonds and occasionally a zircon or epidote; then in the development of the mica mines, some of which furnished some very beautiful beryls and others, garnets. Some of the garnet crystals of wonderful color and brilliancy were frequently found flattened between the plates of mica.

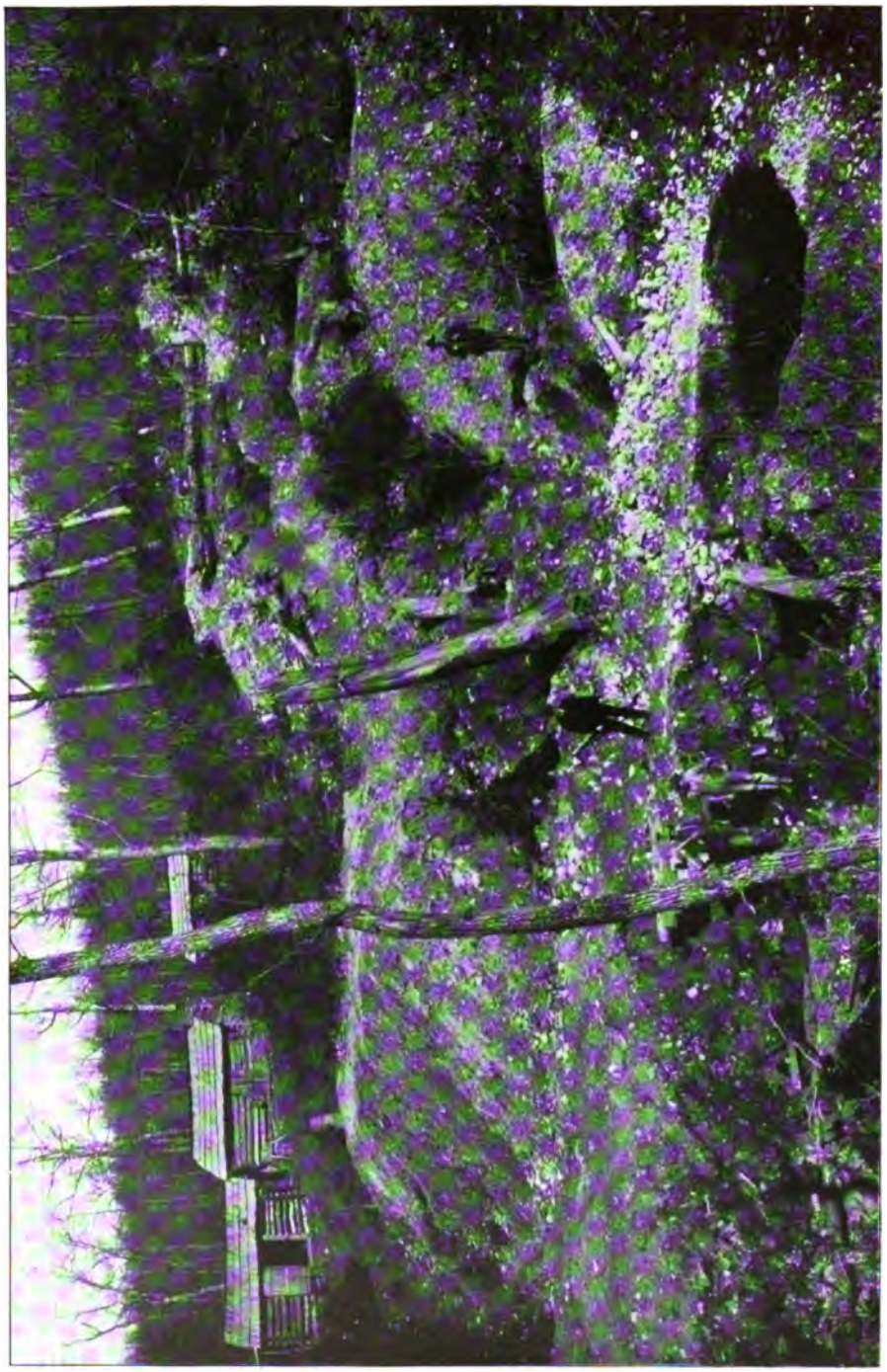
The first systematic mining for gems was undertaken by Mr. C. W. Jenks, in 1871, when he opened the corundum mine, on Corundum Hill, near Franklin, Macon County. This proved interesting scientifically, and many choice gems were obtained; and the name of the Jenks, or Culsagee, mine became noted. The amount of gems found, however, did not warrant permanent operations for gem corundum only, and after a few years the mine was operated for corundum for abrasive purposes. Another promising mine, opened soon afterwards, was the Buck Creek, or Cullakeenee mine, in Clay County; but this has had much the same history. Next came the mining for emeralds in Alexander County, at Stony Point, where crystals had been found loose in the soil formed by the disintegration of the country rock. As this region has never been subjected to glacial action, as the northern part of the country has, anything found in the soil, apart from stream-beds, has its origin presumably near the spot where it is met with. The entire soil and upper portions of the rocks here consist of what Professor Kerr called the "frost drift," *i. e.*, the same as the underlying rock, but decayed and decomposed by frost and weathering in general. Credit should be given here to the late Mr. J. Adlai D. Stephenson, of Statesville, who recognized these conditions and stimulated the country people to search the surface of their fields for such crystals, of

which he gathered a great collection, in the hope of locating mines near the points where anything of special interest was encountered. It was thus that the emerald locality at Stony Point, which also yielded the new and remarkable hiddenite gems, was traced. Later, the beryl mine at Spruce Pine, Mitchell County (Pl. II), was opened, and worked from time to time, affording beautiful beryls. Then came the discovery of true rubies near Franklin, Macon County, which has led to considerable development and to the finding of some crystals which had gem value, although never very great. Near this place occurs also the rhodolite—a garnet between pyrope and almandite. This has been developed by two companies with remarkable success, and apparently more gems in value have been sold from this mine than from all other sources in North Carolina combined. More recent still is the development of the emerald matrix mine at Crabtree Mountain, near Bakersville, in Mitchell County. Here the emerald occurs as small richly colored crystals, thickly strewn through a white matrix of feldspar and quartz; and the whole rock is cut and polished together, as a green and white ornamental stone, which is quite in favor. Amethyst of good quality, but not to any great extent, has been developed in Lincoln and Macon counties.

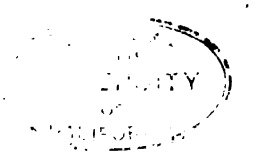
Thus far, with the exception of rhodolite and beryl, the gem mines of North Carolina have not proved remunerative enough to warrant a continued development, either from absence of sufficiently rich material or else from the use of methods that lacked cohesiveness to assure success.

A few notes may be given here as to some of the circumstances connected with mining development and the men who were active in it. General Clingman has been referred to already; another early and very active worker was Mr. C. W. Jenks, who will be mentioned further in relation to the first corundum development. One of the most energetic explorers and discoverers of North Carolina minerals was Mr. J. A. D. Stephenson, of Statesville. In 1888 he prepared for the author a summary of the results which he had attained in the years following the Civil War; and from this little unpublished work the following passages are taken, to show the spirit and the methods of his activity:

The Piedmont region lying between the Catawba and Yadkin rivers, is remarkable for the number of minerals, both common and rare, that are found in unusually fine crystals. Being a native of this section, and an ardent admirer of all the phenomena and beauties of nature, these crystals attracted my attention in early life, and the collection and study of them . . . . convinced me that they were of more than usual interest; and my early experience in the placer gold mines of North Carolina familiarized me with the occurrence of such rare materials as monazite, xenotime, zircon, columbite, etc., in this region; and knowing that these materials are found



WISEMAN BERYL MINE, MITCHELL COUNTY, N. C., 18 MILES FROM MARION.



associated with precious stones in other countries, impressed me with the idea that by . . . . systematic search, valuable gems would be found here, but want of time and opportunity delayed the search until 1874.

I selected this section as the most convenient for my work. But the same indications cross the State from northeast to southeast. In fact, to draw a line . . . . from Paris, Maine, to Gainesville, Ga., it is surprising to me how near it passes all the gem localities east of the Mississippi River.

My plan . . . . was to go among the people of the country, and endeavor to interest them in collecting the different crystals found in their respective sections; this I found an easy matter, especially with the children, as they took hold of the idea readily and many of them soon became familiar with the work, and not only did good service in developing the mineral resources of the State, but many of them have acquired a good knowledge of mineralogy and general natural history.

Mr. Stephenson's discoveries form almost the only exception to the general statement made at the outset, that the discoveries of gems and gem-minerals in North Carolina arose incidentally in the search or mining for gold, corundum, mica, or the rare earths. Mr. Stephenson had described how he set about the search for gems directly, in the assurance that they must exist and could be traced by sufficient endeavor. In almost all other cases, the discoveries have been made accidentally in the course of other mining operations.

A recent letter to the writer from Mr. D. A. Bowman, of Bakersville, for example, states the usual facts as follows:

As to the discovery of beryl, and other gems, this was invariably by mica mining, for outside of a mica vein, I have never known a beryl to be found. In working for black mica, the beautiful beryl at Buchanan Mine was found. It was the same at Grassy Creek, where Wiseman and McKinney found the deep green aquamarines, and then sold to the "American Gem Company."

I identified the beryl found by Wiseman and McKinney and shipped it to Tiffany & Company.

It was Mr. Rorison and myself that first discovered the emerald matrix at Brush Creek Mountain, in 1894 or 1895. . . . . For 35 years I have worked hard to bring to light the various minerals and gems, and through your kind assistance I feel I have not worked in vain, and have been of some little service to my country.

In the same letter, Mr. Bowman gives an interesting account of the first opening of a mica mine, shortly before the war. In 1858, General Clingman, while traveling in the western part of the State, stopped over night with a Mr. Silver, near Bakersville, and was interested to find a window filled with 8 by 10 inch panes cut from sheets of mica, or as it was generally called, isinglass. The very next day, having been shown the spot where this novel material was found, General Clingman hired workmen and began sinking a shaft. Mica was taken out in magnificent

A

Section of a sapphire crystal,
banded blue and yellow, Jenks Mine, Macon County,
North Carolina.

B

Asteriated sapphire,
Jackson County,
North Carolina

C

Ruby,
Jenks Mine, Macon County
North Carolina

D

First sapphire found in matrix
Corundum Hill, Macon County,
North Carolina
Restored to matrix after being cut

E

Sapphire (Brown)
Chiloyan t,
McDowell County,
North Carolina

F

Ruby,
Gower Valley,
Macon County, North Carolina

G

Ruby,
Gower Valley,
Macon County, North Carolina

interest that attaches to it as a local specimen of large size and fine appearance. (See Plate III.)

Another diamond is reported to have been found 9 years before, in 1877, by a small boy, in the same region as the last. It weighed 2⅜ carats, and is described as white and lustrous, but somewhat flawed, and of irregular flattened form, resembling a bean, with the crystal faces obscure. The finder sold it in Marion for a mere nominal sum. Mr. B. B. Price, of Marion, put it for disposal into the hands of Mr. James M. Gere, of Spruce Pine, an extensive buyer and miner of North Carolina mica. He took it to Syracuse, N. Y., and sold it there to Messrs. C. M. Ball & Co., jewelers, for the sum of $18. It was finally sent to New York, where it was cut into a small gem and its identity lost.[7]

Still another crystal is in the State Museum at Raleigh. The particulars of its discovery are not known; but it was purchased by the State with the collection of the late Dr. J. A. D. Stephenson, of Statesville, N. C., who had possessed it for some years, and reported that he had bought it, with other minerals, from a countryman in Burke County. It has an oblong spheroidal form, the faces being curved and rounded; and it weighs 5/16 of a carat. These particulars are given in a recent letter from Mr. T. K. Brunner, Secretary of the State Department of Agriculture at Raleigh.

The latest well established discovery was in 1893, in Cleveland County, near King's Mountain. It was a polished octahedron, weighing ¾ carat, of a bright light canary yellow.

It will be noticed that most of these localities are situated in the same section of the State,—in the mountainous district, lying just north from the northernmost extension of the border of South Carolina. Here the counties of Burke, Rutherford, McDowell, and Cleveland lie closely adjacent, and Mecklenburg only a short distance eastward.

The foregoing list includes all the authentic diamonds thus far discovered in North Carolina. A number of small stones, exhibited as diamonds, have been found at Brackettstown. They are similar to supposed diamonds found by J. C. Mills at his mine at Brindletown, but these were transparent zircon or smoky-colored quartz, the former of which has a lustre readily mistaken by an inexperienced person for that of a diamond. A number of pieces of rough diamond, exhibited as from the same section, have been decided to be of South African, not Carolinian origin. It is to be hoped that the few legitimate discoveries

[7] Addendum to the "Minerals and Mineral Localities of North Carolina," by William Earl Hidden, p. 2, 1889; Reprinted from Jour. of the Elisha Mitchell Scientific Society, 6th year, part II. Raleigh, 1890.

[illegible]

[illegible] just [illegible] Carolina. [illegible] lie [illegible] rd.

[illegible] thus far [illegible] exhibited as [illegible] similar to [illegible] Brindletown, but [illegible] the former of [illegible] person for that [illegible] exhibited as [illegible] South African, not [illegible] imate discoveries

[illegible] North Carolina," by William [illegible] Scientific Society,

A
Emerald.
Stony Point,
Alexander County,
North Carolina
B
Aquamarine.
(Sea Green.)
Spruce Pine,
Mitchell County,
North Carolina
G
Diamond.
Dysortville,
Mc Dowell County,
North Carolina.
F
Hiddenite.
Stony Point,
Alexander County,
North Carolina.
C
Aquamarine (Blue)
Spruce Pine,
Mitchell County,
North Carolina
E
Beryl Cats Eye
Spruce Pine,
Mitchell County,
North Carolina
D
Emerald Matrix
Crabtree Mountain
Mitchell County,
North Carolina

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actually made in this locality will not lead to deceptions, which would greatly retard any natural development of interest. It is quite possible that diamonds may be found widely distributed throughout the auriferous belt of the Carolinas and northern Georgia; and that, in the often rude and hurried methods of gold-washing employed, they may have been overlooked in the past, and now lie buried in the piles of sand that stretch for miles along the water-courses.[8] It is stated that 3 diamond crystals were obtained many years ago on Koko Creek, at the headwaters of the Tellico River, in East Tennessee, on the "Bench lands" of the Smoky or Unaka Mountains. If this statement be correct, it probably points to a western extension of the diamond belt of North Carolina, or to the transportation of the stones thence by streams.[9]

Franklin County is far removed, both geographically and geologically, from all the other points above noted; and indeed in both aspects, a possible relation is suggested rather with the celebrated Manchester, Virginia, diamond. In both these cases, if the diamonds came from the Blue Ridge, they must have been carried a long distance by streams. There is, however, a possible nearer source, in the belt of "Atlantic" or "Tidewater" gneiss, which runs down from New York to and through the Carolinas, forms the rapids in the James at Richmond, and goes on directly toward Franklin County, North Carolina. This is merely a suggestion, however, caused by the geographical isolation of these two occurrences; nowhere else along this gneissic belt have diamonds ever been found.

[8] Gems and Precious Stones of North America, by Geo. F. Kunz, New York, 1890, p. 21. 8vo, 363 pp.

[9] l. c., p. 35.

CHAPTER III.

CORUNDUM GEMS.[1]

While diamonds and gold are found in the Piedmont country east of the mountains, North Carolina's chief corundum rocks are in Madison, Buncombe, Haywood, Jackson, Macon, and Clay counties, where numerous occurrences are known. A second and a third line of localities are recognized, but they are of slight importance. There are occurrences of corundum, however, east of the mountains, in the counties of Gaston, Lincoln, Burke, Iredell, Guilford, and Forsyth. The late Prof. John A. Humphreys called attention to some of these in 18—, in his paper No. 12 of "Natural History Notes on Western North Carolina," and suggested their possible importance in comparison with those farther west. Some of the earliest specimens, also, were collected in Gaston and Lincoln counties, as will be noted further on. But the main corundum region is beyond the Blue Ridge, where it forms a belt or zone of large extent, stretching along the whole course of the Southern Appalachians. The principal corundum gems are the ruby, sapphire, and oriental emerald.

According to Dr. Thomas M. Chatard,[2] of the United States Geological Survey, the corundum region extends from the Virginia line through the western part of South Carolina, and across Georgia as far as Dudleyville, Ala. Its greatest width is estimated to be about 100 miles. This belt has sometimes been called the chrysolite or chromiferous series, owing to the presene of chrysolite containing chromite, from the former of which corundum was believed, by certain authorities, to have been derived by alteration.[3] In this decomposed and altered chrysolite (dunite) throughout the Southern States, corundum is found in place; and the earlier writers on the subject, including such eminent authorities as Dr. J. Lawrence Smith and Prof. Charles U. Shepard,[4] believed it to be confined to the serpentinous rocks of this belt, which represent largely an al-

[1] For more detailed descriptions of corundum occurrences in North Carolina, reference is made to Reports, N. C. Geol. Survey, Vol. I, 1905, on Corundum and the Basic Magnesian Rocks of N. C., by Joseph Hyde Pratt and Joseph Volney Lewis; Corundum and the Basic Magnesian Rocks of N. C., by J. Volney Lewis, Bull. No. 11, 1895; and also Gems and Gem Mining in the South, by Joseph Hyde Pratt; The Southland, Vol. I, Nos. 3 and 4, 1901.

[2] Mineral Resources of the United States, p. 714, 1883-1884.

[3] See Corundum: Its Alterations and Associated Minerals, by Frederick A. Genth, in Contributions from the Laboratory of the University of Pennsylvania, No. I, Philadelphia, 1873.

[4] Corundum and its Gems: A Lecture before the Society of Arts, Boston, 1876.

teration product of chrysolite. Such was the general view during the years following the Civil War, when the mineral resources of North Carolina were beginning to be actively developed.

More recently, it has come to be seen that this is only one phase of corundum occurrence, although much the most conspicuous. The investigation of the Geological Survey, conducted by Dr. Joseph H. Pratt,[5] and Prof. Joseph Volney Lewis,[6] have traced several distinct associations in which corundum appears. Three of these are clearly developed in North Carolina:—(1) In the crystalline schists, as long prismatic crystals, usually opaque, grey, pink, or blue; (2) in the decomposed chrysolite or peridotite rocks, called dunites, that intersect the schists, as igneous intrusions; the crystals often large and variously colored, but very rarely of gem quality; (3) in more or less decomposed basic rocks, with garnets, in the Cowee Valley in Macon County, where the crystals are small, in six-sided tables or to some extent rhombohedral, sometimes transparent and rich red. These last are the "Cowee rubies." The second group corresponds to the chrysolite or serpentine occurrence noted by the earlier writers; the first has been but recently distinguished with clearness from the second. It appears now, through further researches of Dr. Pratt that under this first head are again included two very different modes of geological occurrence,—one in a hornblende gneiss arising from the alteration of an igneous rock and its foliation by pressure, and the other in a true gneiss varying to a quartz schist, which has resulted from the metamorphism of sedimentary strata. These latter gneisses occur separately, extending along the crest of the Blue Ridge, at an elevation of 3000 to 4000 feet, from Rabun County, Georgia, to Clay County, N. C. The corundum appears in irregular bands in the gneiss, evidently belonging to it, and not in veins or dikes. Dr. Pratt concludes that these were originally aluminous shales, and that in the long process of metamorphism, the alumina may have first separated as bauxite (hydrated oxide), and subsequently formed corundum bands parallel to the planes of lamination.

In all the other cases, the corundum is a product of true igneous action, having either crystallized out from a molten rock directly, or formed at the contact zones of such rock with others which it penetrated, by mutual chemical actions under the influence of great heat. The former is a frequent manner in which corundum exists. The extensive deposits lately made known in Ontario, are in a nepheline-syenite, plainly igneous in

[5] Amer. Jour. Sci., Vol. VI, Pt. 4, p. 59, 1898; Vol. X, pp. 295-298, 1900.
[6] N. C. Geol. Survey, Bull. 11, 1896 and Vol. I, 1905.

origin, and the gem corundums of Montana are derived from intrusive dikes. The occurrence in crystalline limestone, in northern New Jersey, like that in Burma, is probably of the other type, a result of contact metamorphism, although Messrs. Brown and Judd have advanced a theory for the Burman mines, that attributes even these to an original igneous source.

The whole question of the geology of corundum,—its origin, mode of formation, etc., has been obscure and uncertain for a long time. Many theories have been advanced, only to be modified by subsequent discoveries. Within a few years past, however, important progress has been made; and though much remains to be ascertained, a number of points have gradually been established.

Among these is the fact that corundum, long regarded as a somewhat rare mineral, is really of more frequent occurrence than was formerly supposed; and also that it has been formed under various conditions and in several distinct ways. As already stated above, it is now known to have been produced (1) by crystallizing directly out of igneous rocks; and (2) by various forms of alteration and metamorphism, in both igneous and sedimentary rocks. The first head is further divided into occurrences in basic and in acidic rocks, and again into cases when the alumina was present in excess in the igneous rock itself, as an original constituent (autogenic), and those when it was introduced in pieces of an aluminous shale traversed by the igneous rock and taken up by it in its ascent (allothigenic). All these cases of occurrence have now been fairly identified in the corundum localities in the United States.

The earlier writers generally held that pure alumina (corundum)was a secondary or derivative mineral, formed by the alteration of other species in which it had previously existed in combination, as a silicate. Its close association with the altered peridotite or chrysolite (dunite) belt of the South Atlantic States, has already been referred to, and the belief of some geologists that the corundum was derived from the chrysolite, by various processes of alteration. The late eminent Dr. F. A. Genth, while not committing himself to any positive statement as to the origin of the corundum, developed a remarkable body of facts as to the alteration of corundum itself into various other and associated minerals.[7] There is not space here to go into any full outline of the course of observation and opinion. This has been very well done by Dr. J. H. Pratt, of the North Carolina Geological Survey, in his recent paper "On the Origin of the Corundum associated with the Peridotites in North Carolina."[8] In this

[7] The Alterations of Corundum; Proc. Am. Phil. Soc., XIII, pp. 361-406, 1873.
[8] Am. Jour. Sci., IV, Vol. VI, No. 31, July, 1898, pp. 49-65.

article he shows how the igneous origin of these peridotites or dunites has come to be gradually established, and the separation of the corundum from them as an original ingredient. In a subsequent and more extended paper on "The Occurrence and Distribution of the Corundum in the United States,"[9] Dr. Pratt describes all the known localities, and the special features of each.

A full and excellent account of the distribution, the geology, and the history and literature of corundum, with special reference to Georgia, has also been given by Prof. Francis P. King, assistant geologist of that State, in his "Preliminary Report on Corundum Deposits in Georgia."[10]

The earliest discovery of corundum in the United States was reported in 1819, by Mr. John Dickson, in an article on the mineralogy and geology of the two Carolinas, published in "Silliman's Journal."[11] The crystals which he obtained came from Laurens District, S. C., a locality which has since yielded a considerable amount of both corundum and zircon.

Of corundum in North Carolina, the first recorded account is the statement by Prof. C. D. Smith, who was the assistant State Geologist under Professor Emmons, that it was found in 1846, but he does not say where or by whom. Dr. F. A. Genth reports that a large mass of corundum was obtained in 1847, in Madison (then a part of Buncombe) County, on the French Broad River, 3 miles below Marshall.

This was a dark blue piece, associated with chlorite and margarite. In 1849 or 1850, Prof. Charles U. Shepard received from Gen. Thomas L. Clingman several pounds of a coarse blue sapphire broken from a large crystal "picked up at the base of a mountain on the French Broad River in Madison County, N. C." This is probably the same discovery as that previously noted.

Whether the Indians knew anything of corundum is uncertain. It is too hard for them to have worked it in any way, and it has not been recognized among any of the minerals occasionally found in graves or mounds. As Professor King of Georgia says, it is not unlikely that some of the pink or blue fragments of crystalline corundum found in the gravels of the Southern States may have been noticed and prized as ornaments; but the aborigines certainly made very little use of it otherwise. A curious fact is noted by Professor King, however, in reference to the corundum mine at Track Rock, in Union County, Georgia,—that near the locality is a rock covered with curious carvings, many of them resembling animals tracks, whence the place derives its name.

[9] U. S. Geol. Survey Bull., No. 180, 93 pp., 1901, and Bull. 269, 175 pp., 1906.
[10] Geol. Survey of Georgia, Bull. No. 2, 133 pp., 1894.
[11] Am. Jour. Sci., I, Vol. III, p. 4.

Possibly the Indians may have employed fragments of corundum in executing these designs on the rock (?).

This first recognition, far to the west, was soon followed by some on the eastern side of the Blue Ridge. In 1852, Prof. R. T. Brumby, of the College of South Carolina, collected specimens of corundum at Clubb (now Chubb) Mountain, in Gaston County, and placed them in the cabinet of the College, where they still remain, with Professor Brumby's dated labels. They are rough crystals and crystalline masses, of dark blue color, covered with the micaceous alteration-products so frequently present; but they have high interest in being perhaps the first North Carolina specimens to be determined, labeled, and placed in a public collection. About the same time Dr. C. L. Hunter discovered corundum in Gaston County, perhaps at the same locality, and Professor Emmons referred to it in his report on the midland counties of North Carolina in 1853.[12] The Civil War began soon after, putting a stop to further research, and it was not until its close that investigations were resumed.

Rev. C. D. Smith, of Franklin, N. C., who in his former position on the State Geological Survey, had become very familiar with the minerals of the State, now discovered most of the important localities in North Carolina. In 1865 a specimen was brought to him from a point west of the Blue Ridge, which he recognized as corundum; he visited the locality, collected specimens, and announced the occurrence. This was the origin of the mining industry now so valuable. These discoveries led to further exploration, and many localities were found in the same region, which have since been more or less developed.

In 1870, Mr. Smith sketched the corundum belt of North Carolina, as running in a southwesterly course across Macon County, where it strikes the Georgia State line, its general direction coinciding with the trend of the Blue Ridge, until it reaches the head of the Tennessee River, when it suddenly ceases on encountering the Nantahala Mountain (a spur of the Blue Ridge here running due north), to reappear 10 miles to the northwest on Buck Creek, whence it pursues its original course of northeast and southwest across the Chunkygal mountains, where it again enters the Blue Ridge. Later investigation has revealed a more extended belt.

Two of the localities in this region have been much the more prominent,—those at Corundum Hill and Buck Creek.

With the opening of the Culsagee (Cullasagee, or Cullasaja) mine, on Corundum Hill, near Franklin, Macon County, by Mr. C. W. Jenks, in

[12] Amer. Jour. Sci., II, Vol. XV, p. 373, May, 1853.

1871, the first systematic attempt to mine gems within the State was begun. From a scientific point of view the operations were most interesting, but the number of gems found did not warrant permanent operations, for gems only, and after a few years mining for this mineral was for abrasive purposes.

This mine, which includes several openings, is situated on the Culsagee or Sugartown Fork of the Little Tennessee River, 8 or 9 miles above (southeast of) the town of Franklin, the county seat, at an elevation of about 2500 feet above the sea. The Corundum Hill is essentially an outcrop of peridotite (dunite), some 10 acres in area, and rising to a height of between 300 and 400 feet. Most of the openings are along the contact of the dunite with the gneiss or schist through which it rises, and follow "contact veins" of corundum. It has often been called the Jenks mine, also the Culsagee and the Corundum Hill, names derived from the locality and from the name of its first operator, Charles W. Jenks, of Boston, Mass. It was subsequently worked by the Hampden Emery Company, of Chester, Mass., under the direction of Dr. S. F. Lucas, and became known as the Lucas mine. It is now owned by the International Corundum & Emery Co., of New York, which also controls several other less important mines in the same neighborhood.

The other prominent locality was the Buck Creek or Cullakenee (also spelled Cullakeenee and Cullakenish) mine, in Clay County, 20 miles southwest of Franklin. It was opened soon afterwards, and has had a similar history. The outcrop is much more extensive, but less work has been done there.

These mines, especially the first, have been described in various scientific papers and reports. One of the earliest published accounts was given by Prof. C. U. Shepard[13] in 1872; another was by Mr. Jenks himself, 2 years later, in a paper read before the Geological Society of London. In 1876, Prof. Rossiter W. Raymond read an excellent paper before the American Institute of Mining Engineers[14]; in 1883, Dr. Thomas M. Chatard, of the U. S. Geological Survey described it again.[15]

Besides these valuable articles, there are the no less excellent references in various reports of the State Survey, by Prof. W. C. Kerr, and in articles by Dr. F. A. Genth, who was associated with him in portions of the survey work, and by Dr. J. Lawrence Smith.

Professor Shepard described the dunite rock very well, and recognized it distinctly as an altered form of chrysolite, referring it to the species

[13] Am. Jour. Sci., II, Vol. IV, Aug.-Sept., 1872.
[14] Trans. Am. Inst. Min. Eng., Chattanooga meeting, May, 1876.
[15] Mineral Resources of the U. S., 1883-1884, p. 714.

known as villarsite. Dr. Raymond fully perceived its character as an igneous intrusion, differing from some other writers on this point, since clearly established. Dr. Chatard describes the Culsagee outcrop as consisting of chrysolite (dunite) mingled with hornblende. The corundum is enclosed among various hydromicaceous minerals, commonly grouped under the term chlorite, between the gneiss and the dunite, from the alteration of which they have evidently been formed. It occurs chiefly in crystalline masses, often of considerable size, and sometimes suitable for gems (Pl. IV, A). At other parts of the mine it is found in small crystals and grains mingled with scales of chlorite, forming what is called the "sand vein." This is so loose and incoherent that it is worked by the hydraulic process; and the small size of such corundum is the saving of much labor in the next process of pulverizing. At Buck Creek the chrysolite rocks cover an area of over 300 acres, and from that point southward the hornblende rocks assume greater proportions, being associated with albite instead of the ordinary feldspar and forming an albitic cyanite rock. There is also found here the beautiful green smaragdite, called by Professor Shepard *chrome-arfvedsonite*, which, with red or pink corundum, forms a beautiful and peculiar rock curiously resembling the eclogite or omphacite rock of Hof, in Bavaria, as Professor Shepard had noted in his early article in 1872.

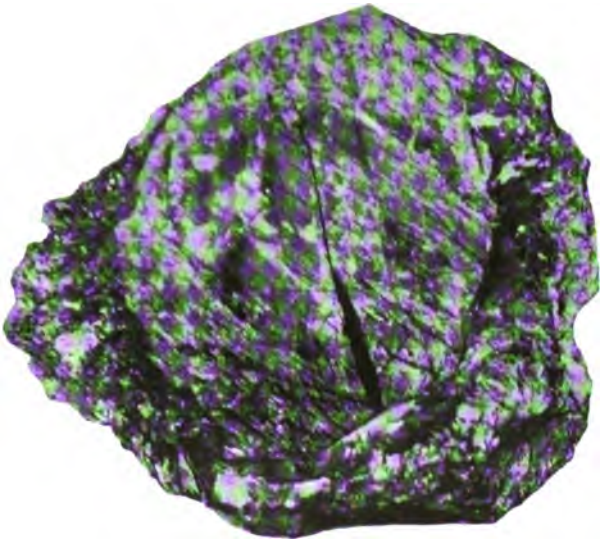
Both these localities have also been recently described, with maps, in the admirable report of Dr. J. H. Pratt and Prof. J. V. Lewis, elsewhere referred to.[16]

The resemblance in the occurrence of the North Carolina corundum to that of Mramorsk in the Ural Mountains, as described by Prof. Gustav Rose of the University of Berlin, has been shown by Professor Genth.[17] There the associated species are serpentine and chlorite schist, sometimes with emery, diaspore, and zoisite, very similar to the chrome serpentine corundum belt of the Southern States. The emery deposits of Asia Minor and the Grecian Archipelago, according to Dr. J. Lawrence Smith,[18] yield that substance in marble or limestone, overlying gneissic rocks; while with it are associated many of the same hydromicaceous and chloritic species that accompany both the New England emery and the southern corundum.

With more particular reference now to the actual gems yielded at these various localities, we may note that they occur in two distinct forms: first, as crystals, of which the usual forms for sapphire are doubly termi-

[16] Corundum and the Peridotites of North Carolina, N. C. Geol. Surv., Vol. I, 1905.
[17] Contributions to the Laboratory of Penn. Univ., No. 1, 1873.
[18] Am. Jour. Sci., II, Vol. X, p. 355, Nov., 1850; and Vol. XII, p. 53, Jan., 1851.

A. TRANSPARENT BLUE AND GREEN SAPPHIRE, NATURAL SIZE, MACON COUNTY, N. C.



B. CORUNDUM, SHOWING ALTERATION, NATURAL SIZE, HAYWOOD COUNTY, N. C.

nated hexagonal pyramids, often barrel-shaped by the occurrence of a number of pyramidal planes of successively greater angle; and second, as nodules of purer and clearer material, in the midst of larger masses of ordinary cleavable corundum. These, when broken or falling out, are sometimes taken for rolled pebbles, which they resemble. This latter, and quite peculiar mode of occurrence is treated of somewhat in the able paper on this mine, read by Prof. Rossiter W. Raymond, in May, 1876, before the American Institute of Mining Engineers, and published in their Transactions.

In regard to the relations of different kinds of corundum, Dr. Pratt says:—"The corundum gem or sapphire localities are usually distinct from corundum localities, although very handsome gems have been found where corundum was mined for abrasive purposes, notably at the Corundum Hill mine."[19]

In 1874, Mr. C. W. Jenks read a paper on the occurrence of sapphires and rubies *in situ* in corundum, at the Culsagee mine, before the Geological Society of London; in this brief but important article he described the location and mineralogical character of the mine, and the fact of the presence of portions in the corundum of true gem quality. The paper attracted much interest, and Prof. David Forbes said that great credit was due to Mr. Jenks, and that he had "discovered the actual home" of the true ruby and sapphire, which had never before been really traced to their sources (see Pl. I).

Some years later, a London periodical made the statement that any one who found the sapphire or the ruby in its original matrix would be called the "King of Rubies," and that his fortune would be assurred. But such is not always the result to those who deserve it. Mr. Jenks was undoubtedly the original finder of the true corundum or sapphire gems in place, and he obtained from this locality nearly all the fine crystals of the best American collections. One of the most interesting of these is a piece of blue corundum with a white band running across it and a place in the center where a nodule had dropped out. This piece was cut and put back in its place, and the white band can be seen running across both gem and rock. (See colored Pl. 1.) Nearly all the fine gems from Franklin, N. C., were brought to light by Mr. Jenks' mining; but although found in their original matrix, they were of such rare occurrence that it was found unprofitable to mine for them alone. The work was subsequently suspended for some time in consequence of the financial crisis of 1873, but resumed by the Hampden Emery Company.

[19] Corundum in the United States, J. H. Pratt, 1901, p. 10 (Bull. No. 180, U. S. Geol. Survey).

The largest crystal ever found, which is 5 times larger than any other known, is one early discovered by Mr. Jenks and described by Professor Shepard.[29] It is now in the cabinet at Amherst College; but much injured by the disastrous fire of 1882, which destroyed so many fine specimens of the Shepard collection. It weighed 312 pounds, and measured 22 inches in length, 18 inches in breadth, and 12 inches in thickness. In form it was a steep and somewhat irregular six-sided pyramid, terminated above by a rather uneven basal plane. Its general color is grayish blue.

In addition to these and other notable crystals, many public collections, besides the American Museum of Natural History (which possesses much the finest series), contain numerous cut gems from this mine.

A blue stone of over 1-carat weight is in the United States National Museum at Washington, and a series of fine red and blue crystals have been deposited there by S. F. Lucas. In the collection made by the late Prof. Joseph Leidy, of Philadelphia, and now also in the National Museum, are several gems from the same mine, including a wine-yellow sapphire of 3¼ carats (660 milligrams); a violet-blue stone of a little over 1 carat (215 milligrams); and three dark-blue ones weighing respectively about 1½ (320 milligrams); 1¼ (250 milligrams); and ¾ (145 milligrams) carats each.

In Dr. Spencer's notes on American gems in the British Museum of Natural History, London, is noted a specimen of corundum from Corundum Hill, Macon County, N. C., which consists of a rough hexagonal prism, 26 cm. long and 18 cm. across, of a reddish color.

In a recent report of Prof. J. H. Pratt, State Geologist, he thus refers to gems from this locality:

> At the Corundum Hill Mines, Cullasagee, N. C., various shades of gem ruby corundum have been found. Two of the best rubies of good color that have ever been found at this mine are in the collection of Clarence S. Bement, of Philadelphia; there are also a number of fine ones in the United States National Museum at Washington. Many of the smaller crystals of various shades of pink to red are transparent near the outer surface and near their extremities, and from these small gems can be cut, but few that are worth $100 have been obtained from them.

Probably the finest emerald green colored sapphire in the world came from the Culsagee mine sand is now in the Morgan-Bement collection at New York. This is the rarest of all the colors of sapphire or corundum gems, and is known as Oriental emerald. The specimen is a crystal

[29] Am. Jour. Sci., IV, Aug. and Sept., 1872.

4 x 2 x 1¼ inches; part of it is transparent, and several very fine gems could be cut from it, see Plate XII.

Another locality in the same county, interesting, though less prominent, is the Mincey mine on Ellijay (properly Elegée) Creek, about 2½ miles northeast of Corundum Hill. Some good ruby corundum occurs here, together with a peculiar brown or bronze variety, known locally as "pearl corundum," which shows distinct asterism, both by natural and artificial light, when the stone is cut *en cabochon*. In natural light these corundums all show a bronze luster and are somewhat similar to the cat's-eye, but in artificial light the star is more distinct. Most of the bronze corundum is in rough crystals, but some have been found that have the prismatic faces smooth and well developed, and these are often dark, almost black, in color. One crystal of this dark kind, found some years ago, yielded gems ⅔ of an inch in diameter. A similar asterism has been noticed in many of the rubies and sapphires from Cowee Valley, and at several other points in the State. According to Von Lasaulx, it is sometimes produced by rifts due to the basal parting. These rifts when examined with the microscope, are seen to be very thin, sharp and rectilinear, and are parallel to the edge between the prism and the base. In other cases asterism is undoubtedly due to rutile or other minute crystals enclosed in the corundum, intersecting each other at an angle of 60°, or in some similar systematic positions.

At the Cullakenee mine, Buck Creek, in Clay County, masses of emerald to grass-green amphibolite (also called smaragdite) are found, through which are disseminated particles of pink and ruby corundum, from the size of a pea to some as large as hickory nuts. The corundum is not of gem quality, but the combination of the green and pink makes very beautiful specimens, and as the rock is hard enough to take a good polish, it might furnish a decorative or ornamental stone of some value. It has been introduced for such purposes under the name of ruby matrix.

A similar association of green amphibolite with corundum, sometimes pink and sometimes dark blue, is found near Elf post-office, on Shooting Creek, in the same county. Other corundum localities in Clay County are the Foster mine, near the headwaters of the north fork of Shooting Creek, and the Herbert mine on Little Buck Creek.

Of late much attention has been aroused by the discovery of rich ruby corundum in small distinct crystals of a different character from any others found in the State, and in a different rock. These have been known as the Cowee rubies, from the locality in the Cowee valley, in Macon County. It has seemed as though here, at last, true gem rubies, equal to those of Burma, had been really found, and much interest has been felt in

the discovery. Thus far, however, no very important results have been obtained, although some of the stones are unquestionably fine, but most of them are small (see Pl. I).

They are unusually interesting and beautiful as crystals, but many of them are imperfect. It is claimed, however, that the percentage of imperfect stones is no greater than it is in the rubies from Burma. Unfortunately, many of the crystals also have inclusions which mar their elegance as gems. The exact locality of this very interesting occurrence is a tract of some 10 square miles lying between Mason's Branch and the Caler Fork of Cowee Creek, affluents of the Little Tennessee River some 6 miles below Franklin, Macon County. Many interesting minerals are found in this area, and there are mica mines there, and mines where the abundant garnet has been worked for use as an abrasive. The beautiful rhodolite garnets, found in close association with the ruby crystals in the gravel and saprolite, will be described separately under garnet.

The discovery and development of the "Cowee rubies" were first described in the volumes of the U. S. Geological Survey (Mineral Resources of the United States), in the writer's annual reports on the Production of Precious Stones, from 1893 to 1896, year by year, and further in that of 1899.[21] Also in 1899, there appeared a full account by Prof. J. W. Judd, Mr. W. E. Hidden, and Dr. J. H. Pratt[22]; and the latter gentleman has since published further accounts in his annual reports, and in his special bulletins on corundum in the United States.[23]

The first published notice in the author's report for 1893, above mentioned, was of the finding of ruby corundum, in small hexagonal crystals, flat or tabular, in an alluvial deposit on the Reeves farm, not far from Franklin, associated with beautiful garnets. The next year's report described the locality as consisting of the valley of a stream, for several miles, in which the rubies were distributed through a gravel bed from 2 to 10 feet thick, overlain by several feet of surface deposit,—a mode of occurrence very similar to that in the Mogok Valley in Burma, where the finest rubies are obtained.

The attention of the author was first called to these rubies by the late Mr. James D. Yerrington, of New York, who had specimens, both cut and uncut, that he had received from Mr. Reeves, of Athens, Georgia, who owned the farm on which they had been found. Two cut gems of ½ a carat each, were set in a flag scarf-pin shown in the Tiffany jewelry

[21] Mineral Resources U. S., Ann. Reps. U. S. G. S., 1893, 1894, 1895, 1896, 1899.
[22] Am. Jour. Sci., IV, Vol. VIII, Nov. 1899, pp. 370-380.
[23] Bulls. U. S. Geol. Survey, No. 180, 1901 and No. 269, 1906.

exhibit at the Columbian Exposition of 1893; these were subsequently unmounted and displayed by the same firm at the Atlanta Exposition of 1895. They now form part of the Tiffany-Lea collection, included in that of the U. S. National Museum at Washington. A number of others (see figures), obtained at about the same time, are in the American Museum of Natural History, New York. A fine series, both of crystals and cut gems, was shown by the North Carolina Geological Survey at the recent Expositions at Buffalo, 1901, Charleston, 1901-02, and St. Louis, 1904.

In 1896, the locality was visited and examined by Mr. C. Barrington Brown, the eminent authority on ruby mining, who had previously prepared an exhaustive report on the Burma region, in conjunction with Prof. J. W. Judd, for the British Government.

In 1899, as above stated, Professor Judd and Mr. William E. Hidden published a joint article, with crystallographic notes by Dr. J. H. Pratt. This account embodied the results of Mr. Brown's visit, of Mr. Hidden's operations on the ground, and of Dr. Pratt's studies on the crystal forms and their relations. It had now become clear that the rubies from this locality occurred in a wholly different association from any other corundum in the State, and the title of the article was "On a New Mode of Occurrence of Ruby in North Carolina." The surrounding rocks are schists and gneisses, often containing corundum, but in elongated crystals and not of gem quality. Only a few miles away are the dunite outcrops of the Culsagee and other localities, already described. But at Cowee the rock is wholly different, and the forms of the crystals also. The first accounts had reported a limestone as the probable source of the valley deposit, and even as the matrix of the crystals, as is the case in Burma. But further study had disproved this statement. Underneath the ruby-bearing gravel, comes a soft decayed rock to which the name of saprolite has been given,—a result of the decomposition of basic igneous rocks, in place. This is sometimes many feet in thickness, but gradually passes downward into the unaltered condition of the same rocks. Trial shafts show that this change begins from a depth of some 35 feet, when portions of the unaltered rock begin to be met with. The original rock, when reached, proves to consist of several related varieties, comprising amphibolite, hornblende-eclogite (garnet-amphibolite of some authors), and a basic hornblende-gneiss, with some feldspars (labradorite and perhaps anorthite). Some of these rocks are doubtless the source of the rubies strewn through the saprolitic material and the overlying gravel, though their actual occurrence in the undecomposed rock has not yet been proved. The crystals are distinct from any others found in North Carolina, but

resemble in form those from Yogo Gulch, Montana (the sapphire variety) which are taken from true igneous dikes; and these flat and tabular hexagonal forms are regarded by students of crystallography as characteristic of corundum that has solidified from a molten igneous rock.

Another corundum occurrence in saprolitic rock, but the crystals blue and more prismatic, is noted by Dr. Pratt at the Reed, or Watauga mine, 6 miles east of Franklin; and red, sometimes ruby, corundum is found in old stream gravels near West Mills; both of these are in Macon County. A number of minor occurrences are known throughout the general region, where there are small saprolitic areas.

There are many other localities of corundum in this group of counties, some of the more important or promising of which may be simply mentioned here. In Macon County, besides the important occurrences already described, corundum appears at Glenville, in chlorite schist; at Nona, on Thumping Creek, in nodules and flat crystals in gneiss; on Hickory Knoll Creek at an elevation of 4,000 feet on Fishhawk Mountain, in dunite; and at the Coweeta mine, of pink color in greenish cyanite. Of late, the emery variety has been found, and to some extent worked, at several points near Fairview Knob, in a basic magnesian rock, the principal mine being the Fairview, near North Skeener Gap, and the Waldroop mine on Dobson Mountain.

Jackson and Transylvania counties have numerous corundum localities, notably in the region along their border, where the town of Sapphire has been named, and the appellation of the Sapphire country is frequently used. Here are found many outcrops of peridotite, with a general N.E.-S.W. course, and frequently associated with corundum. One locality that gives some promise is the so-called gem mine on the property of Dr. Grimshawe, of Montvale. This has been known and to some extent worked, for many years. Rubies of good color, from which a number of fine but very small stones have been cut, have been found here in the gravels of the stream, together with blue and yellow corundum of gem quality. By following up the gravels the corundum was located in a small vein in the decomposed peridotite.

At the Sapphire and Whitewater mines, near Sapphire, fragments of corundum of a fine blue color have been found, from which small but good gems have been cut.

Quite large amounts of commercial corundum have been taken out at the Bad Creek and Socrates mines, and also at the Burnt Rock and Brockton mines; these two are in Transylvania County, the others being in Jackson County, and all in peridotite. Other associations in Jackson County are, along Caney Fork and Chastain's Creek, in chlorite schist; and at Bett's Gap in translucent grayish-white crystals in gneiss.

In Haywood County, 2 miles northeast of Pigeon river, near the crossing of the Asheville road, and 2 miles north of this, on the west fork of Pigeon River, at Presley mine, are found some of the finest colored specimens of blue and grayish-blue corundum, in a pegmatitic dike, and also near Retreat post-office (see Pl. IV, B). At Newfound Gap, red corundum occurs in an outcrop of dunite.

Twenty miles northeast of the Presley is the Carter mine in Buncombe County, where fine white and pink corundum occurs in crystals and in a laminated form in peridotite. Blue, bluish-white, and reddish varieties occur at Swannanoa Gap; and also a little south of the town of Democrat, corundum appears,—all in the same or similar rock.

Yancey County has several localities, the most noted of which are Celos Ridge, 8 miles southeast of Burnsville, where crystals occur in a decomposed gneiss, and Egypt, 10 miles west of the same town, where white crystals, sometimes mottled with blue, are found directly in the decomposed peridotite (dunite). This occurrence is noted as of much interest, by Lewis[1] and Pratt,[2] for although corundum is very largely associated with the rock, the crystals are rarely found actually enclosed in it.

Northeast of these mines, in the line of strike of the whole country rock, corundum is found in gneiss near Bakersville, in Mitchell County; and also southwest, in Madison County, near Marshall, a little north of where Big Ivy River enters the French Broad; here the rock is amphibolite.

Grouped together under the name of the Blue Ridge tract, are a number of localities where the corundum occurs in long bands of quartzose schist that belong in and with the gneisses among which they occur. This was referred to before as a very distinct mode of occurrence, in that the rocks are altered sediments, and the corundum, a product of metamorphic action rather than igneous. These corundiferous schists have been traced for many miles along the crest of the Yellow and Chunkygal mountains. The content of corundum is very small, and these deposits will not be important sources for some time to come. Dr. Pratt makes 4 local divisions;—The Scaly Mountain tract, at an elevation of some 4,500 feet on the southern and southwestern slopes of those mountains, near the headwaters of Beech Creek, a tributary of the Tallulah; the Foster tract, just over the line in Georgia; the Yellow Mountain tract, on the northern slopes of those mountains; and the Chunkygal tract, near the headwaters of Sugar Cove Creek, on the western slopes of the mountains. The first

[1] Bull. 11, N. C. Geological Survey.
[2] Bull. 269, U. S. Geological Survey.

two have been worked somewhat, by the Corundum Mining & Manufacturing Co., of Philadelphia. These localities are all near the southern border of the State, and pass over into Rabun County, Georgia.

The Piedmont Counties.—As was stated above, corundum was early found at some points east of the mountains; and the references to discoveries and collecting by Dr. C. L. Hunter, Prof. J. A. Humphreys, and Prof. Brumby of Columbia, S. C., antedate the Civil War by about 10 years. Since the new epoch of mineral development set in after the return of peace, further discoveries have been made, all of interest, but none as yet of importance. Mr. J. A. D. Stephenson obtained fine hexagonal prisms of pale brown corundum at Belt's Ridge, near Statesville, Iredell Co., and some crystals of fine colors from other neighboring points. Prof. Lewis mentions a black corundum in amphibolite, on the Hunter farm, 8 miles north of Statesville, another occurrence in the same rock, at the Acme mine, and a pink corundum in cyanite at the Collins mine, both in the same vicinity. An old locality, especially noted by Professor Humphreys, is Shoup's Ford, in Burke Co., where the corundum is associated with fibrolite, which sometimes surrounds or encloses the crystals, forming what Professor Humphreys described as "pods." In Gaston County, blue corundum occurs with quartz and mica, at Crowders Mountain and Chubbs Mountain; the latter is the source of the Brumby specimens in 1852; it was then known properly as *Clubb* Mountain, named from an old resident and Revolutionary patriot.

Corundum in grayish-blue crystals in garnet-bearing schists and gneisses is reported from points along the ridge stretching from Carpenter's Knob, northwest, on the borders of Burke, Catawba, and Cleveland counties.

CHAPTER IV.

GEM MINERALS OF THE PEGMATITIC DIKES.

In the pegmatite veins of North Carolina are found so many minerals of gem value[1] that a short description of these dikes is given here.

These pegmatitic veins are interesting not only from a commercial standpoint on account of the value of the mica obtained, but also from a mineralogical standpoint on account of the variety of minerals that they sometimes contain.

In character these pegmatitic dikes are very similar to a granite and have sometimes been called "coarse granite" and, if we could conceive of the constituents of a granite magnified a hundred times or more, we would have an appearance that is very similar to a pegmatitic dike. The main mineral constituents of these dikes are quartz, feldspar, and muscovite mica in varying proportions, sometimes being nearly equally distributed while in others sometimes one and again another will predominate. Sometimes the feldspar, quartz, and mica have separated out in rather small masses while at other times they have separated out on a larger scale and are more or less crystallized.

The associated minerals that occur in these dikes vary with their occurrence and while in some there is a great variety of them, in others they are very rare. The pegmatitic dikes that are observed in North Carolina have furnished the greatest variety of accessory minerals, 45 having been observed from the different veins, at a number of which over 20 different minerals have been observed. Of these accessory minerals the garnet (either andradite or almandite) is by far the commonest and is often the only accessory mineral observed.

The accessory minerals in these pegmatitic dikes are usually well crystallized and a number of them are gem minerals. The following is a list of the minerals that have been identified in the mica-bearing pegmatitic dikes in North Carolina and they are given approximately according to their relative frequency of occurrence:

Quartz (massive, crystallized and smoky).
Albite, Feldspar.
Zoisite (var. thulite).
Menaccanite.
Rogersite.

[1] Joseph Hyde Pratt in "The Southland," Asheville, North Carolina, August, 1901, pp. 120-121.

Microcline, Feldspar.
Oligoclase, Feldspar.
Orthoclase, Feldspar.
Kaolin.
Beryl (Emerald, yellow, and aquamarine).
Muscovite, Mica.
Biotite, Mica.
Essonite, Garnet.
Almandite, Garnet.
Andradite, Garnet.
Tourmaline.
Apatite.
Columbite.
Allanite.
Epidote.
Samarskite.
Gummite.
Autunite.
Pyrite.
Magnetite.
Hatchettolite.
Fergusonite.
Uraninite.
Uranotil.
Phosphuranylite.
Monazite.
Zircon.
Pyrrhotite.
Hematite.
Limonite.
Rutile.
Molybdenite.
Opal (var. hyalite).
Enstatite.
Actinolite.
Cyanite.
Gahnite.
Chabazite.(?)
Graphite.
Pyrophyllite.

Of the minerals given in this list the following have been found of sufficient purity to be a source of gems:

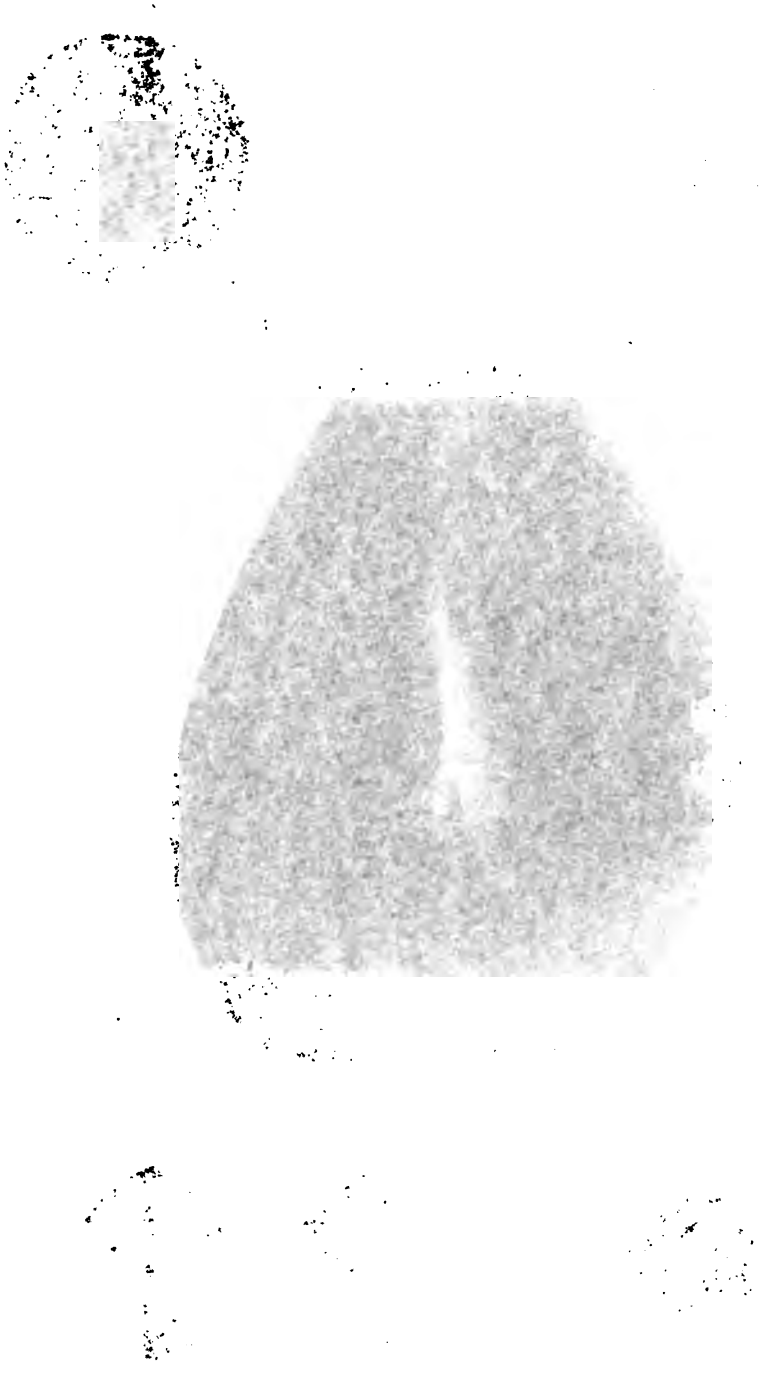
Essonite.
Almandite.
Beryl.
Quartz.
Albite.
Oligoclase.
Orthoclase.
Gahnite.

The following of these pegmatite occuring minerals are precious stones:

Albite, Feldspar.
Almandite, Garnet.
Beryl (Emerald, yellow, and aquamarine).
Cyanite.
Essonite, Garnet.
Opal (var. hyalite).
Pyrite.
Quartz, (massive, crystallized and smoky).
Menaccanite.
Microcline.
Oligoclase, Feldspar.
Rutile.
Zircon.

The following are radio-active:

Allanite.
Autunite.
Columbite.
Fergusonite.
Gummite.
Hatchettolite.
Menaccanite.
Monazite.
Phosphuranylite.
Rogersite.
Samarskite.
Uraninite.
Uranotil.



[illegible] CAROLINA

[illegible]

[illegible] (?)

[illegible]ite.

[illegible] been found [illegible]

[illegible]

[illegible] precious stones [illegible]:

Quartz (massive, crystallized and [illegible])
[illegible]
[illegible], Feldspar.
Rutile.
Zircon.

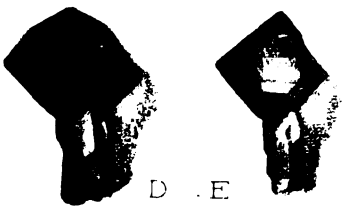
[illegible]

[illegible]
Phosphuranylite
[illegible]
Samarskite
Uranotile
[illegible]

A
Smoky quartz.
(cairngorm stone).
Alexander County, North Carolina.

B
Rutilated Quartz.
Alexander County,
North Carolina

C
Rutilated Quartz.
Alexander County
North Carolina



D E
Amethyst.
Henry Lincoln County,
North Carolina

F
Amethyst
Tesonty Creek,
Smith Bridge Township,
Macon County, North Carolina.

The following are commercial minerals:

Graphite.	**Muscovite (mica).**
Kaolin.	**Orthoclase.**
Magnetite.	**Pyrophyllite.**

It is the breaking down of these veins that form many of the smaller often microscopic minerals found in the detritis of the gold veins.

THE FELDSPARS.

Several interesting varieties of feldspar occur in North Carolina, among which the following may be especially noted as the ones which are of importance as gem material.

Orthoclase.—A very interesting variety of sunstone was found by J. A. D. Stephenson at the quarry in Statesville, N. C.; the reflections are as fine as those of the Norwegian, but the spots of color are very small. Several hundred dollars' worth from this locality have been sold as gems.

Microcline.—This feldspar is closely related to orthoclase; it is sometimes of a very beautiful light green color, and is then known as amazonstone, and valued for cutting and polishing for ornamental purposes. Several localities in North Carolina furnish this mineral, especially the Ray mica mine, Yancey County.

Oligoclase.—In December, 1887, specimens of feldspar were sent to the writer[2] by Daniel A. Bowman, who had found them at a depth of 380 feet in the Hawk Mica mine, 4 miles east of Bakersville, N. C. They proved to be a variety of oligoclase, remarkable for its transparency. The clearest piece measured 1 by 2 by 3 inches. One of the two varieties is of a faint window-glass green color, and contains a series of cavities, surrounded and fringed by tufts of white, needle-shaped inclusions called microlites; these tufts vary from 1/50 to 3/50 inch (0.5 to 1.5 millimeter) in diameter and are quite round, resembling those that are occasionally present in the Ceylonese moonstone. The wonderful transparency of the oligoclase and the whiteness of the inclusions give the whole mass a striking resemblance to the lumps of glass so commonly obtained from the bottom of a glass-pot. It was mistaken for this until its highly perfect cleavage was noticed. Recently some material of a slightly different character has been obtained at the mine. Cleavage masses of a white, striated oligoclase, 3 inches long, were found containing nodules about $\frac{2}{5}$ inch to $\frac{3}{5}$ inch (10 to 15 millimeters) across, which were as colorless and pellucid as the finest phenacite and entirely free from

[2] See Mineralogical Notes, by George F. Kunz, Am. Jour. Sci., III, Vol. XXXVI, p. 222, Sept., 1888.

the inclusions found in the greenish variety. This translucent variety, like the other, shows no striae.

The following analysis by Prof. Frank W. Clarke, made from a faint green variety, shows it to be a typical oligoclase. The specific gravity was determined to be 2.651. This has been cut into a transparent gem, and may be advantageously used for spectroscope, microscope, and other lenses.

Silica	62.60
Alumina	23.52
Ferric Oxide	.08
Manganous Oxide	trace
Lime	4.47
Potassa	.56
Soda	8.62
Loss by ignition	.10
	99.95

Labradorite (*Opalescent feldspar*).—On the road to Charlotte, Mecklenburg County, and near Bakersville, Mitchell County, specimens showing a slight blue chatoyancy are found. This domestic labradorite is scarcely used at all in the arts, as the mineral from Labrador is cheaper and of a much superior quality, and takes a fine polish.

Leopardite.—This is a rock composed largely of whitish feldspar (orthoclase and plagioclase), spotted black, perhaps by manganese oxide, and named from its leopard-like appearance. It is abundant near Charlotte, Mecklenburg County, and also in Gaston County. It is not a definite mineral, but a variety of porphyry with disseminated crystals of quartz, and occurs in large masses as a rock, so that it would furnish a good ornamental stone, if polished. This variety of spotted feldspar is peculiar to North Carolina, and has been described in detail in the report on Building Stones.

The beryl, zircon, and other gem minerals, which are also constituents of pegmatitic dikes, are described in the following chapters.

CHAPTER V.

QUARTZ AND OPAL.

Quartz in its various crystalline forms,—rock-crystal, amethyst, and smoky quartz,—occurs at many points in North Carolina, and in some cases of fine quality (Pl. V). The non-crystalline varieties, such as agate, jasper, etc., have not, on the other hand, been found to any important extent in the State, until very recently in the chrysoprase workings near Asheville.

CRYSTALLINE VARIETIES.

Rock-Crystal.—Much interest was created in 1886, when a remarkable mass of rock-crystal, weighing 51 pounds, was sent to Tiffany & Company, New York. It purported to be from Cave City, Va., but was subsequently traced with certainty to the mountainous part of Ashe County, N. C.[1] The original crystal, which must have weighed 300 pounds, was unfortunately broken in pieces by the ignorant mountain girl who found it, but the fragment sent to New York was sufficiently large to admit of being cut into slabs 6 inches square and from half an inch to an inch thick. This superb crystal, if it had not been broken, would have furnished an almost perfect ball 4½ or 5 inches in diameter. It is now in the Morgan Collection at the American Museum of Natural History, New York. A visit to the locality by the author traced this specimen to the place of its discovery near Long Shoal Creek, on a spur of Phoenix Mountain in Chestnut Hill Township. There have also been found at 2 places, 600 feet apart (about 1 mile from the former locality), 2 crystals, weighing respectively 285 and 188 pounds. The larger of the 2 was 29 inches long, 18 inches wide, 13 inches thick, showing 1 pyramidal termination entirely perfect and the other less complete. All these crystals were lying in decomposed crystalline rock consisting of a coarse feldspathic granite, and were obtained either by digging or by driving a plow through the soil. Altogether several dozen crystals have been found in this vicinity weighing from 20 to 300 pounds each, and future working will undoubtedly reveal more. These large crystals are often very irregular and pitted, like many of those from St. Gothard. Of those now in

[1] Proc. Am. Assoc'n Adv. Sci., Vol. XXXV, p. 239, 1886.

the Morgan-Tiffany collection at New York, the most irregular was 20½ pounds in weight, with the entire surface rough and opaque like ground glass, and almost spherical in form, but the interior perfectly transparent. In a few instances, they had a coating of rich green chlorite that penetrated to the depth of an inch. This, when left on the quartz, gave the cut crystal, after polishing, the effect of a pool of water with green moss growing on the bottom.

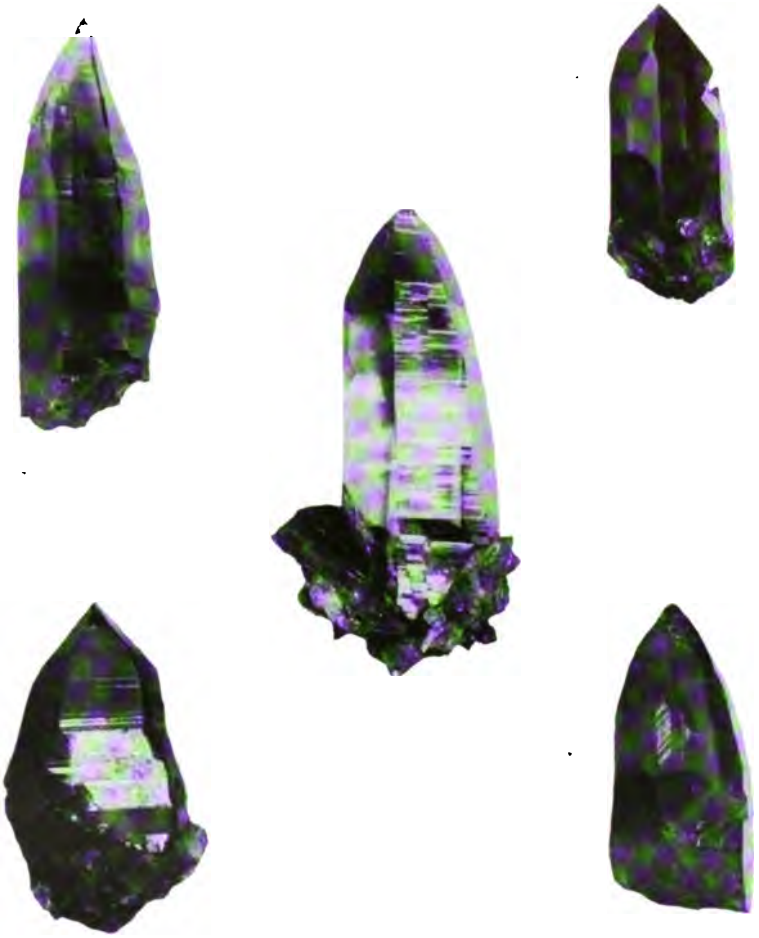
Many beautiful articles have been made from this Ashe County material. One was an elegantly carved vinaigrette or scent-bottle, exhibited at the Paris Exposition of 1889. A crystal ball 5 inches in diameter, and a number of art objects, all of American workmanship, made from the same material, were shown at the Columbian Exposition at Chicago in 1893, and some of these are now in the Tiffany collection in Higinbotham Hall, in the Field Columbian Museum in that city. These were all made in the Tiffany ateliers in New York.

By far the most important piece from this locality, however, was a magnificent crystal obtained in 1888 by the author at the same locality. This was worked up into a special design, and exhibited as the finest piece of American lapidary work ever executed in rock crystal. It was the most important art object of stone at the great Paris Exposition of 1900, where it was shown by the makers, Tiffany & Company. It now will form part of the F. A. Matthiesen memorial gift, lately presented to the Metropolitan Museum of Art in New York City.

Another North Carolina locality was reported in 1896, by Mr. R. M. Chatham, who described crystals up to 40 pounds in weight, from Elkin, in Surrey County. Some large crystals are also known from South Carolina; and it is probable that a good deal of rock-crystal, capable of use in the arts, exists in the mountain region of the South.

The report of the finding near Bakersville of transparent crystals of quartz, weighing 642 pounds and 340 pounds respectively, was premature, as the specimens proved to be veins of translucent quartzite, with the crystalline markings of a group rather than of a single crystal. The clear spaces, which were to be observed only on these crystalline sides, would hardly afford material for a crystal ball an inch in diameter, and with this exception they are almost an opaque white, with flaws. Notwithstanding this error, it is certain that some localities in North Carolina have yielded larger masses of clear rock-crystal than any other State in the Union until the recent developments in Calaveras County, California.

In Alexander and Burke counties, N. C., crystals of white as well as of smoky quartz have been found, in which were spaces that would cut into



A. QUARTZ CRYSTALS (SMOKY) NATURAL SIZE, ALEXANDER COUNTY, N. C.

B. AMETHYST, LINCOLN COUNTY, N. C.

clear crystal balls of from 2 to 2½ inches (Pl. VII, A). One of these from Alexander County, measuring 2 3/16 inches, is in the State Museum of Natural History at Albany, N. Y. A very interesting bead made of rock-crystal, fluted and drilled from both ends, is in the collection of A. E. Douglas, in New York City. It is evidently native work, as it is improbable that foreign traders would use white rock-crystal beads, when glass would answer the purpose as well.

The Indians who lived in North Carolina previous to the advent of the white man occasionally noticed quartz crystals, as is shown by some being found in the mounds. They also realized the beautiful cutting edge that this material would possess if it were chipped in the form of an arrow point; and so they used up great quantities of the white quartzite for this purpose, and occasionally a transparent piece of quartz, either white or smoky. Many such objects,—of the chase or of war,—made of this beautiful material have been found, and are to be seen in our museums. Within the past 10 years, however, the demand for these transparent arrow-heads has increased, until the demand has so much exceeded the supply that some of the inhabitants, especially in Mitchell County, with remarkable cupidity and cleverness, have chipped arrow-points out of quartz crystals. These are in many ways quite as beautiful as the Indian work, but have no archæological value, of course, though they are to some extent sold as articles of ornament.

The highly modified crystals from White Plains, in Surrey County, and Stony Point, Alexander County, and also from Catawba and Burke counties, N. C., are worthy of note as being crystallographically unequalled anywhere, and as having formed the subject of special memoirs by Dr. Gerhard von Rath[2] (Pls. VI, A and VIII, A). A beautiful opalescent quartz has been found in Stokes County.

Amethyst (*Purple Variety of Quartz.*)—An almost unique gem in the collection of the United States National Museum at Washington is a piece of amethyst found at Webster, N. C., and deposited by Dr. H. S. Lucas. The present form is just such as would be made by a lapidary in roughly shaping a stone, preliminary to cutting and polishing it. It was turtle-shaped when found, though the shape was unfortunately destroyed by chipping, and was said to have borne marks of the handiwork of prehistoric man. It now measures 3⅜ inches (6 centimeters) in width, 1½ inches (4 centimeters) in thickness, and weighs 4¾ ounces (135.5 grams). It is perfectly transparent, slightly smoky, and pale at one end, and also has a smoky streak in the center.

[2] Naturw. Verein, Westphalia, 1888.

In Haywood County a number of crystals of amethyst have been secured, some of which were cut into very fine gems.

In 1894 Mr. T. K. Brunner, of Raleigh, reported a yield of amethysts from Catawba, Macon, Wake, Lincoln, and other counties in the State; and in 1898 he stated that large amethysts of good color were still found in Lincoln County, together with smoky and lighter colored varieties.

In 1901 there was a decidedly promising effort to prosecute mining for amethysts on a commercial scale at Tessentee, on the creek of that name, in Smith Bridge Township, Macon County. Here a large vein of crystalline quartz occurs in an altered pegmatite. The development during the year was entirely in a kaolinized rock, in which the amethyst crystals, ranging from ½ inch to 3 inches in length, were found loose with the quartz and mica in the kaolin. The entire vein was exposed to the depth of 20 feet by a landslide. It would appear that further working should disclose the amethysts in the rock. The crystals are light and dark in color, and the dark spots are often of the deepest purple. No finer amethysts have been discovered in this country, and several thousand dollars worth of crystals were sold as the proceeds of the first development work.

Amethyst crystals, often of great beauty and of much crystallographic interest, have been found in various parts of the State, sometimes in remarkable quartz groupings, such as the so-called capped crystals, with purple tops raised upon slender stilt-like white crystals; others with rare faces, and then again enclosing water, especially from Lincoln County (see Pls. V, VI, B, and VII, B).

Smoky Quartz.—At Taylorsville and Stony Point, North Carolina, a number of clear pieces of this material have been found that cut fair stones weighing over an ounce each. In Alexander, Burke, Catawba, and adjacent counties, smoky quartz crystals which would afford fine gems are frequently met with. They are generally from 1 to 5 inches in diameter, sometimes of a citron or light yellow color, and often in groups weighing up to 100 pounds and over, quaintly grouped and often very clear. Crystals weighing as much as 40 pounds have been taken from the vicinity of Elkin, in Surrey County. Smoky and citrine quartz abound also in Iredell and Mitchell Counties.

At Stony Point, near Hiddenite post-office, Alexander County, N. C., have been found from time to time in the gneissoid rocks, pockets of quartz crystals varying from absolute pellucid and transparent to a dark smoky color. These are of wonderful brilliancy and purity, and range from an inch in length to a large size; but they are particularly remarkable from the fact that the faces of the crystals are highly and peculiarly developed,

A. SMOKY QUARTZ CRYSTALS, 7/16 NATURAL SIZE, HIDDENITE P. O., ALEXANDER COUNTY, N. C.

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sometimes with great complexity (Pl. VI, A). They have furnished the subject for several monographs on the crystallography of quartz, notably those by Dr. Gerhard von Rath, of Bonn, and by Dr. Gill, of Cornell University. Some of the large complex groups are very interesting from their remarkable twinning-masses from 150 to 200 pounds, being made up of many crystalline faces, while in general contour a single large crystal. They stand quite unique as examples of beautiful color and marvelous crystallization (see Pls. V and VI, A).

The remarkable smoky crystals with included cavities, from Alexander County, are referred to further on, under quartz inclusions.

Rose Quartz.—Specimens of rose quartz from Dan River, Stokes County, N. C., show a beautiful opalescence, and the existence of like quartz, as well as asteriated quartz, in two other counties, Iredell and Cabarrus, was determined in 1894.

Quartz Inclusions (sagenite).—North Carolina has yielded more of this material for gem purposes than all other American localities together.

Rutilated quartz of unexcelled beauty, the rutile brown, red, golden or black, has been brought to light in many places in Randolph, Catawba, Burke, Iredell, Jackson, and Alexander counties, especially the last, where in 1888 crystals of quartz, 3 inches in length, and filled with rutile the thickness of a pin, were secured at Stony Point (Pl. V). Beautiful series of these formerly in the collection of J. W. Wilcox, of Philadelphia, are now in the Morgan-Bement collection in New York. In 1901, fine rutilated quartz, well crystallized and perfectly transparent, was developed, together with handsome garnets, in the monazite mines near Shelby, Cleveland County.

Hornblende in quartz is reported as found in Burke, Alexander, and Iredell counties.

Mining operations at Stony Point, N. C., have brought to light a number of crystals 4 by 3 inches, and masses of quartz 6 by 3 inches, some of the former filled with what appears to be asbestos or byssolite, forming an interesting and attractive material susceptible of being cut into charms and other objects. Magnificent polished specimens are in the Morgan-Tiffany and Morgan-Bement collections. The inclosures of what is seemingly göthite in minute red, fan-shaped crystalline groups or tufts, form also a beautiful and interesting gem stone.

Among other inclusions, some of which might be utilized for gems, the following may be mentioned from North Carolina: Quartz, including scales of hematite from King's Mills, Iredell County; quartz containing crystals of green spodumene (hiddenite) from Stony Point; inclusions of

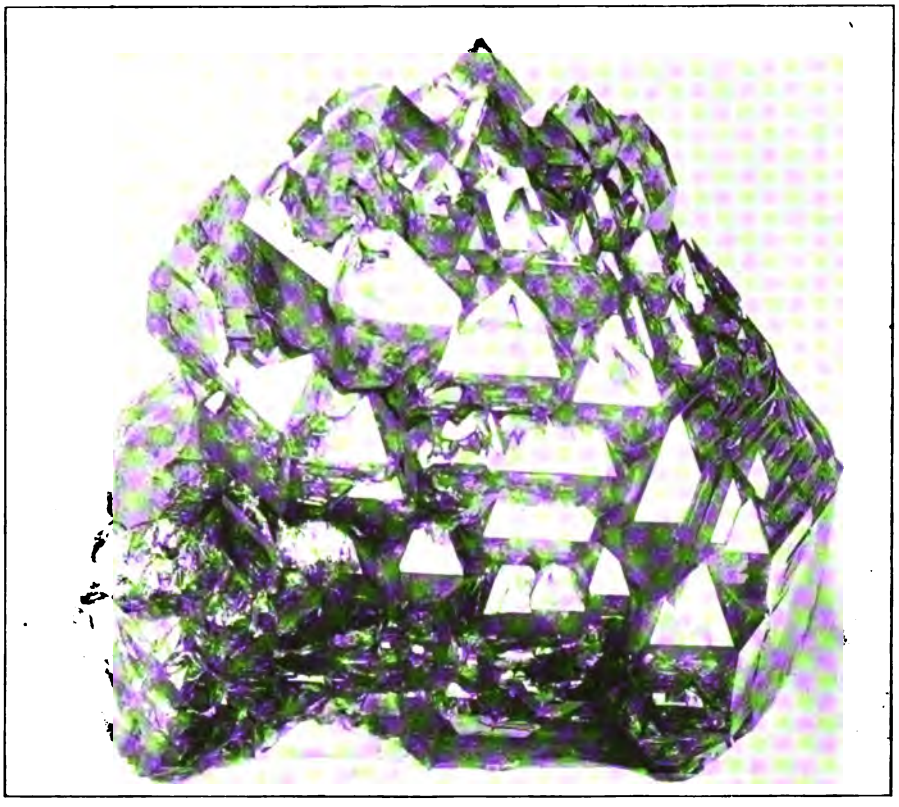
muscovite mica, that are green when viewed through the side of the prism, and of green chlorite, from several other localities in Alexander County.

A remarkable specimen of this kind, that was a "nine-days wonder" some years ago, was the so-called Gibsonville emerald. This was a stone weighing 9 ounces, plowed up near Gibsonville, Guilford County, which was pronounced a genuine emerald by some local expert, who tested it, and with the microscope showed that it contained various small diamonds. Its value was estimated up in the thousands, and $1000 was reported to have been refused for it by its owner, who, as it was believed to be the largest known emerald, expected that it would bring him a fortune. Being, therefore, too valuable to be be entrusted to an express company, he put himself to the expense of a trip to New York, where his prize proved on examination to be a greenish quartz crystal, filled with long hair like crystals of green byssolite or actinolite, on which were series and strings of small liquid-cavities that, glistening in the sun, had led to the included diamond theory. The best offer that he received for the stone was $5.

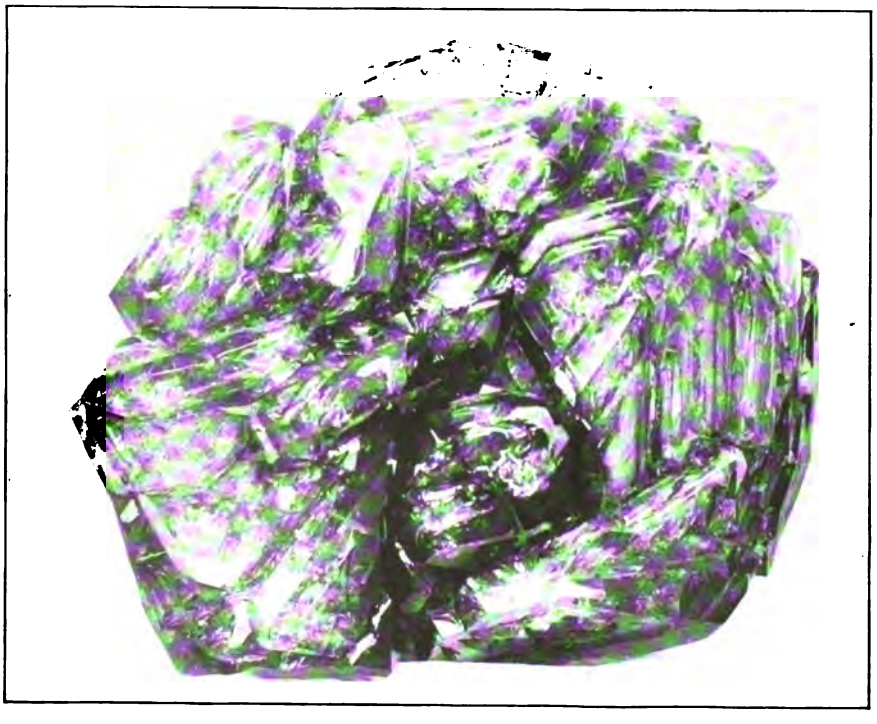
Fluid Inclusions.—In March, 1882, Mr. William E. Hidden described and illustrated before the New York Academy of Sciences some unparalleled specimens obtained at Stony Point, Alexander County—the emerald locality elsewhere noted.[3] Here some 400 pounds of choice large crystals of smoky quartz were taken out of a "pocket" in a quartz vein, besides much of less fine quality. These crystals were filled with cavities containing a clear lustrous fluid, and of extraordinary size, those of an inch long being not uncommon, and some of double that length. The largest was 2½ inches by ¼ of an inch. So abundant were they that at times the crystals seemed to be made up of thin walls of quartz, separating a multitude of elongated cavities, parallel to the rhombohedral or prismatic faces of the crystals (Pl. VIII, B).

It is a matter of great regret that such unique specimens could not have been studied with the minute care given by Professors Dana and Penfield to those of Branchville, Conn. But now comes the singular conclusion of this account. The whole body of these crystals, carefully taken out and put aside as great treasures, were shattered into fragments in a single night, by the temperature falling below the freezing point. The contained fluid was evidently, as in the Branchville quartz, principally water, and its expansion in freezing destroyed the entire body of specimens. Those with few cavities exploded with sharp reports, and pieces were blown as much as 15 feet away. Those filled with small cavities were

[3] On a Phenomenal Pocket of Quartz Crystals; Trans. N. Y. Acad. Sci., March, 1882.



A. GROUP OF QUARTZ CRYSTALS, PARALLEL CRYSTALLIZATION, 5/8 NATURAL SIZE, LINCOLN CO., N. C.



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reduced to little heaps of fragments frozen together in a coherent mass. All that remained for the illustration of Mr. Hidden's paper before the Academy, were flakes of flat pieces, parallel to the faces of the rhombohedron, and filled and clouded with elongated and often rod-shaped cavities, in great numbers and of conspicuous size.

So-called quartz pseudomorphs after calcite cleavages occur at a locality 2 or 3 miles northeast from Rutherfordton, Rutherford County, and frequently contain irregularly shaped cavities filled with water, which, if broken out in good shape, could be utilized as curious ornaments. This variety of quartz was also found by J. A. D. Stephenson in Iredell County. This occurrence was named and described by Mr. William E. Hidden of New York, and shown to be due simply to quartz filling irregular cavities between the mica crystals in a pegmatite rock. It is known as "box quartz."

NON-CRYSTALLINE QUARTZ.

As was stated above, these varieties have not been very prominent in North Carolina.

Chalcedony.—A rich fawn and salmon colored chalcedony has been obtained near Linville, in Burke County, and fine agates and chalcedony at Caldwell's, Mecklenburg County, near Harrisburg and Concord, Cabarrus County, and in Granville and Orange counties, and at some other localities in the State. A fine green-colored variety intermixed with black hornblende, that would afford gems an inch across, was found some years ago in Macon County, and moss agate near Hillsborough, in Orange County.

Chrysoprase.—This valuable variety of chalcedony, colored green by oxide of nickel, has recently been found in Buncombe County, near Morgan Hill, about 16 miles from Asheville.[4] It appears in several parallel seams or veins, having a general N.E.-S.W. course, and within a few feet of each other. At the surface, the color was pale green, but as the rock was opened down to some 4 feet, the tint became deeper and richer. Only a little test work has yet been done, and the extent and commercial value of the material cannot at present be determined. The stone polishes very well, and if darker in color the deposit would have considerable value.

Jasper.—In North Carolina fine jasper, banded red and black, is found in Granville and Person counties; bright brick-red and yellow at Knapp's, Reed's Creek, Madison County; at Warm Springs; at Shut-in-Creek in

[4] Min. Res. U. S., 1902, p. 57 (U. S. G. S. report).

Moore County; also in Wake County, and elsewhere. Black jasper (basanite) also occurs somewhat, and a beautiful spear-point, 5 inches long, and a number of arrow-points, made from this material, have been found near Statesville.

OPAL.

Opal has been found but very sparingly in North Carolina and, with the exception of the hyalite variety, the only specimen that has been found was near Asheville, Buncombe County, and is of a delicate pink color.

Hyalite.—This mineral has been found at the Culsagee Mine, Macon County; the Carter Mine, Madison County; near Concord, Cabarrus County; in Burke County; and in limonite geodes found in the decomposed dunite near Elf on Shooting Creek, Clay County. Nowhere, however, is it of importance, though its presence is of scientific interest.

CHAPTER VI.

BERYL GEMS AND SPODUMENE (HIDDENITE).

BERYL (EMERALD, AQUAMARINE, GOLDEN BERYL).

This gem, chemically a silicate of alumina and glucina (or beryllia) and ranking among the most valuable of precious stones, is found quite extensively in North Carolina. Its commoner variety, beryl, occurs at many places in the State, and sometimes of beautiful gem quality; these are the aquamarines, blue to light green and the yellow or golden beryl. We will first treat of the precious variety, emerald.

Emerald Beryl.—Very few genuine emeralds have been found in the United States; and a number of reported specimens, assumed to be such, have proved upon examination to be only deep green beryls. The true emerald owes its color to a minute amount of oxide of chromium. Some beryls are of a very rich light green, and closely resemble emerald, so that they may easily be regarded as such; but they lack the depth of color so valued in the real emerald (see Pls. III and IX). The chief localities are Alexander and Mitchell counties, N. C., where emeralds, or beryls suggesting them occur. In the former it has been found at several different points, with quartz, rutile (some of the finest known), dolomite, muscovite, garnet, apatite, pyrite, etc., all in fine crystals. One of these places, Stony Point, is about 35 miles southeast of the Blue Ridge, and 16 miles northeast of Statesville, N. C. The surface of the country is rolling, the altitude being about 1000 feet above sea level. The soil, which is not very productive, is generally a red, gravelly clay, resulting from the decomposition of the gneissoid rock, and under these circumstances it is easy to find the sources of minerals discovered on the surface. Prof. Washington C. Kerr's theory of the "frost-drift" is well illustrated by the conditions that prevail throughout this region. The unaltered rock appears at Stony Point at a depth of 26 feet and is unusually hard, especially the walls of the gem-bearing pockets.

An exceptionally clear and reliable account of the search for minerals in Alexander County which resulted in the final uncovering of the important emerald and beryl deposits of Stony Point, has been given by the

developer of the first emerald mine in this country, William E. Hidden,[1] in 1881, and we cannot do better than quote his words. He writes:

Sixteen years ago, the site of the mine now being worked was covered with a dense primitive forest. Less than 10 years ago (1871), this country was mineralogically a blank; nothing was known to exist here having any special value or interest. Whatever we know of it to-day is due directly or indirectly to the earnest field work done here in the past 7 years by J. A. D. Stephenson, a native of the county, now a well-to-do and respected merchant of Statesville, N. C. Under a promise of reward for success, he engaged the farmers for miles around to search carefully over the soil for minerals, Indian relics, etc., and for several years he enjoyed surprising success in thus gathering specimens. The amount and the variety of the material gathered in this way was simply astonishing, and his sanguine expectations were more than realized. To be brief . . . . I will state that from a few localities in the county Mr. Stephenson would occasionally procure crystals of beryl of the ordinary kind, but now and then a semi-transparent prism of beryl, having a decided grass-green tint would be brought to him. These the farmers named " green rocks " or " bolts," and became the principal object of the people's searchings. Mr. Stephenson had told them that a dark green beryl would be valuable if clear and perfect, would in fact be the emerald and for them to search more carefully than ever to find one. Surely, he had informed the people aright and had given them a *rara avis* to look for. It is sufficient to say that within a period of about 6 years there was found on 3 plantations in this county, loose in the soil, a number, say 10, of veritable emeralds, none of which, however, were dark-colored or transparent enough for use as gems. All of these specimens went into Mr. Stephenson's collection, with the single exception of one very choice crystal obtained at that locality by the late John T. Humphreys, which crystal is now in the New York State Museum at Albany, after first being in the collection of the late Dr. Eddy, of Providence.

The following historical account is from unpublished notes on North Carolina gems, prepared for the author by Mr. Stephenson himself in 1888:

The first beryl I collected suitable for cutting, was found early in 1875, at the locality now known as the Emerald and Hiddenite mine. It was a beautiful aquamarine, but only partly suitable for cutting. A few weeks later, I obtained at this locality my first emerald; it was small and rather opaque, but of fine color, and the file-like markings on its planes were very distinct. During 1876, I collected two others at the same locality. . . . During 1877, Mr. I. W. Miller brought me 2 emeralds found on his mother's farm, 2 miles northeast of the Emerald and Hiddenite mine. They were of good color and quite transparent, but very rough on the surface. This promising locality is still undeveloped.

[1] The Discovery of Emeralds in North Carolina, by W. E. Hidden. Privately printed, 8vo., 4 p., 1881, and also Trans. N. Y. Acad. Sci., 1882, pp. 101-105.

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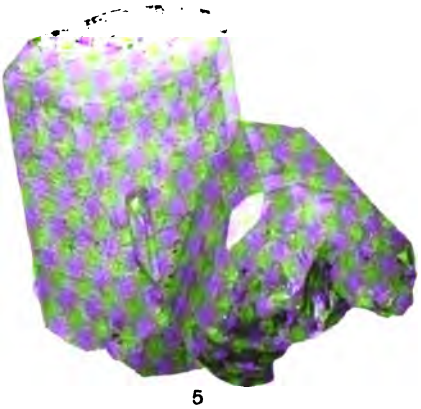

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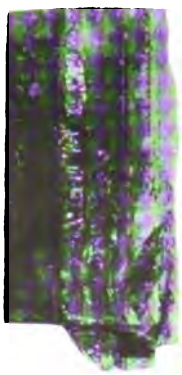

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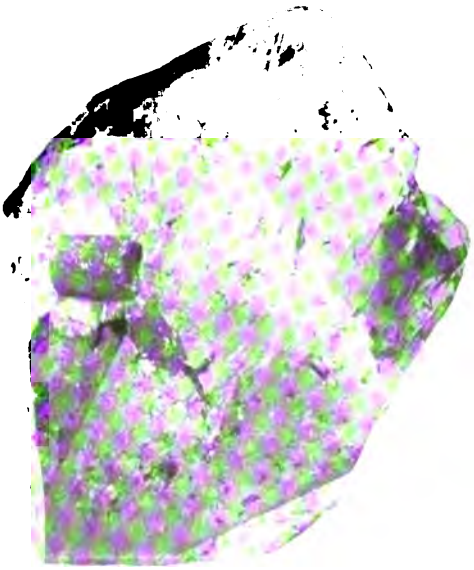

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1. BERYL (EMERALD), ALEXANDER COUNTY, N. C.
2. BERYL (EMERALD), STONY POINT, N. C.
3. BERYL, ALEXANDER COUNTY, N. C.
4. BERYL (EMERALD) WITH RUTILE, ALEXANDER COUNTY, N. C.
5. BERYL CRYSTALS, GROUP.

During . . . . 1883, Mr. J. O. Lackey brought me 36 small emeralds, ... found in a vein of dark mica on his farm a short distance southwest of the Emerald and Hiddenite mine. One or two other occurrences in the same region are also reported in these notes.

In July, 1880, Mr. Hidden undertook to follow up the field-work of Mr. Stephenson systematically, by engaging men to dig a series of ditches on a selected site, where at least half a dozen pale beryls had been uncovered by a farmer while plowing. These ditches were dug in different directions, so as to cut the strata of the prevailing country rock (gneiss) at various angles. After this work had been carried on for 5 weeks without success, a so-called "blind vein" or pocket was discovered at a depth of 8 feet. Only a few emeralds, and those of small size, were found in this pocket, but outnumbering the emeralds 50 to 1, emerald-green spodumene was brought to light, which later received the name of hiddenite from Dr. J. Lawrence Smith, of Louisville, Ky., who was the first to determine its true chemical nature (Pl. III). By further work, eleven other like pockets were opened during the year, within an area of 40 feet square, all carrying emeralds in small quantities, and three besides the first containing hiddenite or the spodumene emerald also. Other pockets were found that yielded quartz, rutile, monazite, and mica crystals of great beauty. In others the walls were covered with finely crystallized dolomite and calcite and transparent apatite, as well as the former minerals.

The gem-bearing "pockets" referred to are expansions of quartz veins that traverse the gneiss rock of the region, having generally an east and west course and a dip toward the north. They are usually quite narrow, but on being followed downward, are found to widen out occasionally and form these cavities, which may be several inches wide and a foot or more in length, or in rare cases much larger. There are other quartz veins also, of more irregular course, which do not appear to develop these cavities or yield any of the gems. The gneiss rock decomposes in place to a depth often of many feet; and then the quartz crystals and pieces, the mica and beryls or emeralds, and in short all the harder minerals of the veins and pockets, are left lying in the soil formed by the decayed and disintegrated gneiss. The presence of these minerals on or near the surface, therefore, serves to those who understand their source, as an indication or "sign" of the presence of such veins in the rock beneath. This was the principle, as has been shown, that guided Mr. Stephenson in his pioneer work.

In 1881, a corporation called the Emerald and Hiddenite Mining Company was organized to work the property at Stony Point, and prosecuted

the search for gems irregularly, for periods varying in length, for several years. Since 1885, however, but little has been done, owing to some legal disputes as to the property.

The largest emerald crystal found during this mining work was 8½ inches in length and weighed nearly 9 ounces (Pl. III, p. 8). It is now in the Morgan-Bement collection at New York. This was one of nine crystals contained in a single pocket, all excellent in color and partially transparent, but somewhat flawed. One was 5 inches in length and others were over 3 inches (Pl. III).

One of the most noteworthy gems cut from the product of this mine was from a crystal found in a pocket at a depth of over 43 feet. Its color is a pleasing light green and it weighs 4 23/32 carats. In 1887, at a depth of about 70 feet, another crystal was obtained that yielded a cut stone of 5 carats. Both of these are too light in color to rank as fine gems. The two largest, and a series of the smaller ones, went into the cabinet of Clarence S. Bement, now the Bement-Morgan collection in the American Museum of Natural History. Some fine ones are also in the British Museum. The rich emerald color in many of these crystals is confined to a border from 2/100 to 3/100 of an inch in thickness around the edge and near the termination of the crystals. If this edge were thicker, fine gems could be cut from it.

The value of the emeralds in this deposit was relatively small compared with that of the many slender crystals of hiddenite. Both these species are in part silicates of alumina, but they differ in the other basic element present, which, in hiddenite, is lithia, while in the emerald it is glucina. Both gem stones owe their color to the same substance, oxide of chromium. The emeralds found in this mine were very rarely without flaws, while the hiddenite was notably free from such defects, and varied in shade from a yellowish green to the deepest blue-green, often oddly combining both extremes of color in the same crystal.

The chemical composition of the emerald beryl is shown in the analysis given below of a leek-green colored beryl from Alexander County:

Analysis of Emerald Beryl.[1]

Specific Gravity, 2.703.

Con-tituent.	Per cent.
Silica	66.28
Alumina	18.60
Ferrous oxide	0.22
Beryllia	13.61
Water	0.83
Total	99.54

[1] F. A. Genth, Analyst.

In the soil overlying the rock and resulting from its decomposition, nine crystals of emeralds were found, later, all doubly terminated and measuring from 1 to 3 inches (25 to 77 millimeters) in width. The latter crystal is very perfect as a specimen; it is of fine light green color and weighs 8¾ ounces, or only ¼ ounce less than the famous Duke of Devonshire emerald crystal (Pl. III). Another crystal measuring 2½ inches (63 millimeters) by 11/12 inch (25 millimeters) is filled with large rhombohedral cavities, formerly containing dolomite. As mineral specimens these are quite unique.

Some peculiar features pertaining to the emeralds and beryls from this region, are particularly noted by Mr. Hidden.[2] "They appear," he says, "as though filed across the prismatic faces." The basal plane is also often pitted with minute depressed hexagonal pyramids, that lie with their edges parallel to one another, and to the edge of the di-hexagonal prism. Rarely, though, crystals are found with perfectly smooth and brilliant faces. The emerald color is often focused on the surface and fades gradually to a colorless central core, which feature is of exceeding interest when the genesis of the mineral is considered.[3] A similar etching or corrosion appears in beryls from Colorado and those from Pala, California. A remarkable fact is that we have here a green beryl (emerald) and emerald green spodumene (hiddenite), and in the Pala, California, mine, we have lilac spodumene (kunzite) and pink beryls.

Some beryls and emeralds of pale color were also collected by Mr. J. A. D. Stephenson, 1 mile southwest of the Stony Point deposit and a short distance from the place where the same mineral was found by Mr. Smeaton, of New York. Such discoveries tend to show that the deposit is evidently not the only one, and that there is still encouragement for future working in this region.

In July, 1894,[4] a new locality of true emeralds, in the western part of the State, was discovered by Mr. J. L. Rorison, a pioneer miner of mica, and Mr. D. A. Bowman, on the Rorison property, 14 miles from Bakersville, and about the same distance from Mitchell's Peak, Mitchell County. Here, at an elevation of 5000 feet, on Big Crabtree Mountain occurs a vein of pegmatite some 5 feet wide, with well defined walls, in mica-schist. It outcrops for perhaps 100 yards, with a north-and-south strike (Pl. X).

This vein carries a variety of minerals besides its component quartz and feldspar, among these being garnets of a translucent reddish color, and black tourmaline, the latter abundant in slender crystals; beryls, white,

[2] Am. Jour. Sci., III, Vol. XXXIII, p. 505, June, 1887.
[3] See Rep. Dept. Mining Statistics, George F. Kunz, 1903.
[4] 16th Ann. Rep. U. S. Geol. Sur., Part IV, p. 600, 1894.

yellow, and pale green; and the emeralds. These last are chiefly small, 1 to 10 mm. wide by 5 to 25 mm. long, but some have been found two or three times the size of the largest above-named. They are perfect hexagonal prisms, generally well terminated with basal planes, and are of good color, with some promise for gems. They very strikingly resemble the Norwegian emerald from Arendal.

It will be noticed that the occurrence here is entirely different from that in Alexander County, being not in veins of quartz, but in a pegmatite dike. The latter is the usual situation in which beryls are found, from New England to the Carolinas, and also the large deposits of mica suitable for mining. This emerald locality has been lately worked by a New York company, and, although but few perfectly transparent gems have yet been obtained, a beautiful ornamental stone has been developed. The crystals vary from $\frac{1}{8}$ of an inch to $1\frac{1}{4}$ inches in diameter, and are rarely over 1 inch in length. Though not clear, they have rather a fine emerald color, and penetrate the quartz and feldspar in an irregular manner. This green and white mixture is very pleasing; and as the feldspar has a hardness of 6.5, the quartz of 7, and the emerald of about 8, the whole can be cut and polished together. Pieces are cut *en cabochon,* showing sections of one or more emerald crystals on the top and sides of the polished stone. The name of "emerald matrix" is given to this ornamental gem material (see illustration in Morgan-Tiffany collection) (see Pl. III). This property, which was worked quite extensively in 1906 by the American Gem and Pearl Company, of New York, produced some perfectly transparent crystals of emerald which cut good gems up to $\frac{3}{4}$ carat in weight.

Far to the southwest of Stony Point and some 50 miles south of the emerald locality near Bakersville, a second new occurrence was noted in 1897 by Mr. J. Meyer of Charlotte, N. C., who had found near Earle's Station, in that State, between Blacksburg, S. C., and Shelby, N. C., a broken fragment of emerald of good color, better than anything observed from North Carolina, although somewhat flawed; it was cut into a facetted stone, of tapeziform, or sub-triangular shape, weighing 4 15/16 carats, that quite closely resembles the material from the Muzo mine of Colombia.

Aquamarine, Yellow and Golden Beryl.—This mineral, as above stated, is found at many localities in North Carolina, and sometimes of quality fine enough to yield choice gems. It will be noted that beryl localities are met with on both sides of the Blue Ridge, both in the Piedmont region; and west of the mountains. Here again, for the development of these and many other forms of mineral wealth in North Carolina, in the years following the devastation of the Civil War, a lasting debt of honor is due to Mr. J. Adlai D. Stephenson, of Statesville, and also to the late Gen.

EMERALD MINE, CRABTREE MOUNTAIN, MITCHELL COUNTY, N. C., ABOUT 25 MILES FROM MARION.

Thomas L. Clingman, who after serving as a brave officer in the Southern army, turned his energies to the cultivation of the arts of peace and the improvement of the natural resources of his State (see Pls. III, IX, and XI).

Mr. Stephenson published accounts from time to time of his researches and discoveries, beginning soon after the war, and continuing for a number of years. A number of beryl localities are noted by Mr. Stephenson in the counties of Alexander, Burke, Caldwell, Cleveland, Macon, Mitchell, and Yancey, some of them yielding choice material (Pl. IX). The remarkable discovery of emerald beryls at Stony Point, Alexander County, has been already described under emerald; but there are numerous occurrences of beryl in the State, closely resembling those of New England, both in size and variety. Mr. Stephenson called the attention of the author to a dark green beryl, weighing 25.4 ounces, part of which would furnish gems of some size, that was found in January, 1888, near Russell Gap Road, Alexander County, by a farmer plowing. This locality, about 10 miles from Stony Point, is the largest beryl deposit affording gems that has been opened in North Carolina. It is noteworthy that the highly modified beryls of this region occur rarely, and only when associated with spodumene or albite, and also that the white or pale greenish beryls are found with the deepest green spodumene. It has before been noted that the quartz and beryl of Alexander County are more highly modified when implanted on the feldspathic layers of the walls of the pockets. We have here a green spodumene and a green beryl (emerald); we have the same minerals, rose or lilac colored (kunzite) and rose beryl, at Pala, California. Two emerald beryls found in 1881, at a depth of 34 feet, were in a little cavity, the walls of which were almost covered with crystals of albite twinned parallel to the base. Only four emeralds were found, averaging about 1 cm. in the three dimensions. The pocket was free from all decomposition whatever. The crystals were of good color, transparent, and had their commoner planes well polished, but they differed to some extent in habit.

Some of the North Carolina beryls, especially the fibrous, green, opaque beryl from Alexander County, would furnish cat's-eyes, although not very fine.

A rich yellow crystal was reported in 1888 by Mr. Stephenson, as found in a quartz boulder, with finely crystallized tourmaline, near Little River Church, Alexander County. Beryl, resembling the Siberian, occurs in greenish-yellow and deep green crystals, in the South Mountains, 9 miles southwest of Morganton, Burke County; also in the Sugar Mountains at Shoup's Ford, Dietz's, Huffman's, and Hildebrand's. A rich

blue-green crystal in quartz was found at Mill's gold mine, Burke County, and a fine transparent green crystal from that vicinity is now in the cabinet of M. T. Lynde, of Brooklyn, N. Y. Another Piedmont locality is at Wells, in Gaston County.

Some of the beryls from the neighborhood of Statesville are of unusual interest from their crystalline forms; these have been described and in part figured by Mr. W. E. Hidden.[5]

Passing to the counties west of the Blue Ridge, several good localities are known where fine beryls occur, generally in pegmatite dikes, like the Bakersville emeralds. Clear green beryls have also been obtained at Balsam Gap, Buncombe County; Carter's mine, Madison County; Thorn Mountain, Macon County, and at one or two points in Jackson County. The following, however, are more important:

Blue beryl in fine crystals that afforded fair gems was found near the Yancey County line, and golden beryl in the same vicinity, as noted by Dr. Pratt. Some crystals 2 feet long and 7 inches in diameter, with small clear spots, which would cut into gems, occur 4 miles south of Bakersville, and near Grassy Creek, both in Mitchell County (Pl. III). Fine blue-green aquamarine is known at Ray's mica mine on Hurricane Mt., Yancey County.

The Grassy Creek locality, just noticed, has attracted some attention recently as a source of fine aquamarine. It is situated on Brush Creek Mountain, Estatoe P. O.,[6] Mitchell County. The beryls occur in a pegmatite dike that cuts across the country rock (gneiss) at a low angle, instead of conforming to the steep lamination of the latter, as do the ordinary mica veins. These last are chiefly muscovite, while the dike consists of quartz and albite, with black mica (biotite), garnet, black tourmaline, titanic iron and beryls. Most of the latter are opaque and yellowish, the bright green ones being only occasionally found, and not always in the dike, but sometimes in the adjacent mica-schist,—as though a product of contact alteration. The best crystals have a fine aquamarine tint, and some have yielded very perfect gems of more than a carat in weight. Some honey-yellow beryls also occur, sufficiently clear for cutting, but these are rare.

Another locality in Mitchell County, very promising as a source of aquamarines, is the Wiseman mine at Flatrock, near Spruce Pine P. O. Here the beryls occur not in a dike, as in the last instance, but in connection with veins of muscovite mica that run with the gneiss rock.

[5] Am. Jour. Sci., Vol. XXII, August, 1881.
[6] J. H. Pratt. Jour. Elisha Mitchell Sci. Society, Vol. XIV, Part 2, 1897, p. 80.

BERYL CRYSTALS, GROUP, NATURAL SIZE, BURNSVILLE, N. C.

LIBRARY
OF THE
UNIVERSITY
OF
CALIFORNIA

Several colors are found here; some are of fine aquamarine tint, and have yielded very perfect gems of more than a carat; less frequently they are honey-yellow, with portions clear enough to be cut; while rich blue ones, equal to any of those from Brazil, have also been obtained in the course of the past 15 years, first by desultory working and then by the most systematic operations under the American Gem Company, of New York City. Large quantities,—thousands even,—of magnificent blue gems weighing from 1 to 20 carats, have been taken out here. (See Pl. II.)

At the Littlefield mine, on Tessentee Creek, Macon County, clear aquamarines have been obtained which have cut into beautiful gems.

At the Charleston Exposition of 1901,[7] Dr. J. H. Pratt exhibited, among other choice minerals of North Carolina, a crystal of golden beryl 1½ inches in diameter and 2¼ inches long, obtained from an Indian mound near Tessentee Creek, not far from the Littlefield mine, and hence presumably from that locality. This is the first instance recorded of a beryl crystal found deposited in an Indian grave.

Another important locality in Macon County is the McGee mine. Here the gems are sea-green and occasionally yellow, and are found in quantity.

A fine representation of the North Carolina beryl is to be seen in the museum of the State University at Chapel Hill, together with the other minerals of the State, collected by the late Mr. Stephenson, in the course of his enthusiastic explorations, and whose cabinet was most appropriately secured by the State.

HIDDENITE OR LITHIA EMERALD.

This is a stone which is peculiar to North Carolina, and hence possesses especial interest in any account of the minerals of that State. The circumstances under which it first came into notice have already been mentioned under Emerald, with which it was found, at Stony Point, Alexander County, in about 1879. Mineralogically, it is a variety of spodumene, a well-known silicate of alumina and lithia, usually found in large rather coarse crystals, opaque and of no beauty. Occasionally, however, it is transparent and richly colored (Pl. III). The first occurrence of this form of it in the United States, was in these small brilliant, green crystals in North Carolina; a second has lately attracted much attention in San Diego County, California, where the crystals are large and of a rose-lilac tint; this variety is the new gem-stone called kunzite.

The history of the North Carolina discovery is as follows:

About 1879, some crystals of a yellow and yellowish-green mineral,

[7] Report Dept. Mining, Charleston Exposition, 1901.

supposed to be diopside, were found at Stony Point, Alexander County, N. C., associated with beryl, quartz, rutile, garnet, dolomite, etc. These crystals soon came into the hands of J. A. D. Stephenson of Statesville, who sent the best of them to Norman Spang, of Pittsburg, Pa., a noted collector of choice minerals. About 2 years later Mr. Stephenson called the attention of William E. Hidden to this mineral, and to the locality; Mr. Hidden then sent specimens for examination to Dr. J. Lawrence Smith, of Louisville, Ky., who found, on investigation, that the mineral was not diopside but a transparent variety of spodumene. The crystals were first found loose in the soil with emeralds, but systematic mining revealed them attached to the veins of the wall-rock (Pl. XII, A). The spodumene is generally more or less altered, hence its pitted or eaten-out appearance; but when found in the rock, the crystals are quite perfect and unchanged. They are all transparent and range from colorless (rare), to a light yellow, into yellowish-green, then into deep yellow emerald-green. Sometimes an entire crystal has a uniform green color, but generally one end is yellow and the other green. Its hardness is on the prism faces, 6.5, and across them, according to Doctor Smith, nearly that of the emerald; but a series of experiments proved it to be somewhat less. At first considerable difficulty was experienced in cutting it, owing to its remarkably perfect prismatic cleavage, which is very lustrous. Gems have, however, been cut up to 2½ carats in weight. Specific gravity, 3.18 to 3.194.

Specimens of the crystals and of cut stones, have gone into all important public and private collections in the United States, and to some extent abroad. Dr. Spencer, of the British Museum, has recently described several specimens there contained, in a report to the Director, Dr. Fletcher, as follows:

HIDDENITE: Alexander County, N. C.

A faceted stone of a rich emerald-green color, perfectly transparent, and with only 1 or 2 small cracks. Weight, 0.494 gram.

A piece of matrix bearing 2 or 3 small crystals. Also numerous isolated prismatic crystals up to 2½ centimeters in length; many rather pale in color, but 3 crystals, presented by Mr. Hidden, in 1893, of a rich emerald-green.

The yellow tinge exhibited by this mineral in even the darkest green gems will prevent it from competing with the emerald, since it is this very quality that has kept down the prices of the Siberian demantoids, or Uralian emeralds, as the green garnets are variously termed. The finest crystal of lithia emerald ever found is in the Morgan-Bement collection at New York. (See Pl. III.) It measures 2⅞ inches (68

millimeters) by ½ inch (14 millimeters) by ⅓ inch (8 millimeters). One end is of very fine color, and would afford the largest gem yet cut from this mineral, weighing perhaps 5½ carats. In Dr. Augustus C. Hamlin's cabinet is a fine gem weighing about 2 carats; and a cut stone of fine color, and a good crystal are in the collection of Col. W. A. Roebling. Dr. J. Lawrence Smith[8] says that the crystals, when cut and polished, resemble the emerald in luster though the color is not so intense as in the finer varieties of the latter gem. Prof. Edward S. Dana says that, owing to its dichroism, it has a peculiar brilliancy which is wanting in the true emerald. Thomas T. Bouvé, of Boston, says: "One might infer from the statement made of the great brilliancy of both the hiddenite and garnet, when compared with the emerald, that this should decide their relative beauty; but it is not the case, for the emerald has a beauty of its own, in its deep and rich shade of color, that will ever make it rank at least an equal in loveliness with the newer aspirants for favor."[9] When the hiddenite was first introduced, it had a considerable sale because of its novelty as an American gem and because of the newspaper notoriety it gained through the controversy that arose as to its discovery. Hence for a time the demand exceeded the supply, which, from the desultory working of the mine, was limited. Thus a 2½ carat stone was sold for $500.00, and a number of stones brought from $40.00 to over $100.00 a carat. The total sale of all the gems found, from the beginning of operations in August, 1880, to the close of 1888, amounted to about $7500.00, the yield in 1882, during which the preparatory work was done, being about $2000.00. At the time of the discovery, this was supposed to be the first occurrence of transparent spodumene; but Pisani, in the Comptes Rendus for 1877, announced a transparent yellow spodumene that had been found at Minas Geraes, Brazil, where it exists in large quantities and has been extensively sold as chrysoberyl. The writer saw nearly a ton of broken crystals of this mineral at Idar, Germany, in 1881, whither it had been sent for cutting. A stone from Brazil weighing 1 carat is in the United States National Museum, as also a series of crystals and cut stones from North Carolina. At Branchville, Conn., spodumene is found in opaque crystals 4 or 5 feet long and a foot in diameter, almost entirely altered to other minerals. In spots, however, it is transparent enough to furnish small gems of an amethystine color. The alterations which have taken place have entirely changed it to what might almost be called a defunct gem; otherwise, these crystals would have afforded gems

[8] Am. Jour. Sci., III, Vol. XXI, p. 128, Feb., 1881.
[9] Proc. Boston Soc. Nat. His., Vol. XXIII, p. 2, Jan. 2, 1884.

over an inch in thickness and several inches in length. The color before the alteration was probably much richer pink. It is of mineralogical value only.

Within the past year, the discoveries in San Diego County, California, have brought to light spodumene of a similar color with the little remnants at Branchville, but entirely clear and unaltered.

The North Carolina mineral was given its name by Dr. J. Lawrence Smith (who first determined its true character) in honor of Mr. W. E. Hidden. The crystals are slightly inclined prisms in form, ranging from quite small up to perhaps 2 inches in length and from ⅓ to ½ of an inch in diameter, for the largest. The first crystal of any size that was found, was shown in the remarkable North Carolina gem-exhibit at the Charleston Exposition of 1901-02. Notwithstanding the interest which attaches to this peculiar and beautiful American gem, no further developments of it have been made for several years, owing to the mines at Stony Point being closed under litigation.

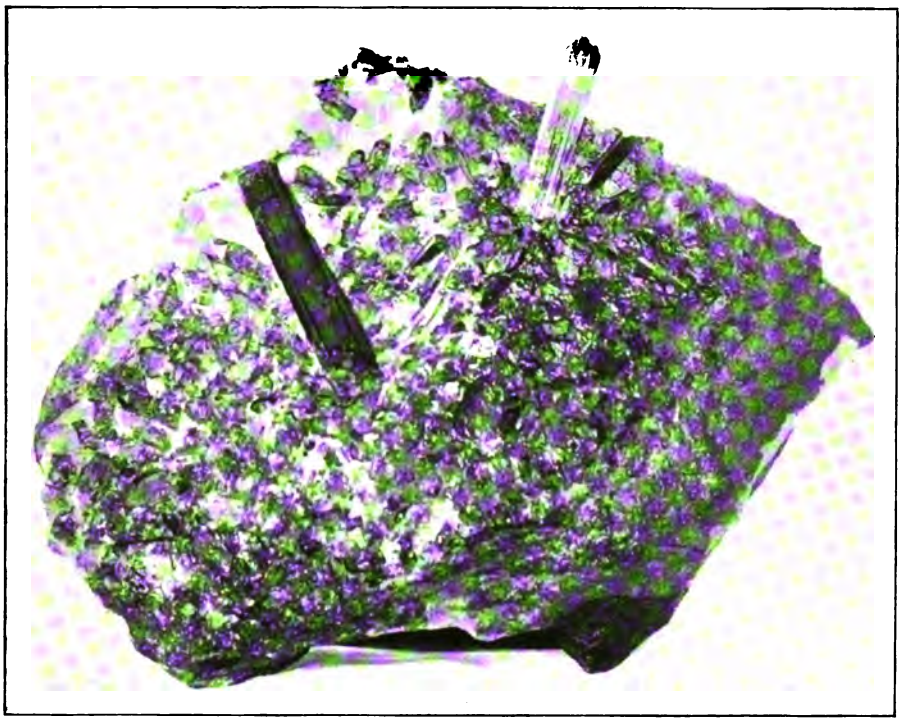
The chemical composition of hiddenite is given in the following table of analyses:

Analyses of Hiddenite.

Specific Gravity, 3.152-3.189.

Constituent.	Per cent.[1]	Per cent.[2]
Silica	63.95	64.35
Alumina	26.58	28.10
Ferric Oxide	....	0.25
Chromic Oxide	0.18	.....
Ferrous Oxide	1.11	.....
Lithia	6.82	7.05
Soda	1.54	0.50
Potassa	0.07	.....
Water	.....	0.15

[1] F. A. Genth, analyst, Am. Jour. Sci., III, 23, 68.
[2] J. Lawrence Smith, analyst, Am. Jour. Sci., III, 21, 128.



A. SPODUMENE (HIDDENITE) IN MATRIX, NATURAL SIZE, STONY POINT, N. C.

B. CYANITE, NATURAL SIZE, BURNSVILLE, N. C.

[illegible]

[illegible]

[illegible] near [illegible], some large enough to cut gems of a carat or more.[1] Very elegant crystals of large size have been found at Amelia Court House, Virginia, in albite pegmatite. [illegible] is not red, but of a peculiar rich brown [illegible] (Pl. XIII.)

Almandite is the most frequent variety, and the one that has been mined for garnet paper and other abrasive purposes, including a so-called "emery," for which tons of it have been crushed. The color is red, of many shades, ranging to brownish and purplish reds. The peculiar play of color observed in some of the South Carolina garnets is usually due to inclusions. In Burke, Caldwell, and Catawba counties are found large dodecahedral and trapezohedral almandite crystals coated externally with a brown crust of limonite, the result of superficial alteration, but

[1] Gems and Precious Stones of North America, New York, 1890, pp. 79-83.

usually showing a bright and compact interior when broken. They are sometimes as fine in color as the Bohemian garnets, and should find a ready use for watch-jewels and other like purposes. Some crystals have been found weighing 20 pounds each. Although not fine enough for gems, these might be cut into dishes or cups measuring from 3 to 6 inches across, as has been done in India. A very large quantity of these garnets has been found about 8 miles southeast of Morganton, and also near Warlick, in Burke County. Here they have been extensively mined for abrasive use and also near Hall's Station in Jackson County, where garnet wheels are manufactured.

Bohemian or pyrope garnets.—This garnet of good color, that has furnished gems, has been found in the sands of the gold-washings of Burke, McDowell, and Alexander counties. This species has a more blood red tint than the preceding, and is used largely in the garnet jewelry made in Bohemia, whence the name; it is the same also that passes under the name of Cape ruby, from South Africa, and Arizona ruby, from the territory of that name.

Rhodolite.—This is by far the most important variety of garnet in North Carolina, and is found nowhere else, indeed, so that it possesses peculiar interest. Since it has been recognized and developed, it has proved to be also the most valuable gem produced commercially in the State. The locality is much the same as that of the Cowee rubies, in Macon County, in the gravels of streams heading on Mason's Mountain, and on the mountain itself at some points. When first observed it was regarded as a very beautiful and brilliant light-colored form of almandine; but analysis subsequently showed that it is a variety intermediate between that and pyrope, in fact an inter-mixture of the two, in the proportion of $\frac{2}{3}$ pyrope and $\frac{1}{3}$ almandine.

The first mention of these Macon County garnets was apparently due to Mr. A. M. Field, of Asheville, in 1893,[2] and was made by the author in his report on the production of precious stones for that year, and again in 1897.[3] In the following year, a paper was published by Mr. W. E. Hidden and Dr. J. H. Pratt, in which the whole subject was treated fully, the analyses described, the nature of the stone determined, and the name of rhodolite proposed for it as a new variety.[4] This name is from the Greek word *rhodon,* a rose, from the resemblance of its color to some kind of roses and rhododendrons. The mineral shows a light shade of fine red, without the dark aspect that belongs to most garnets, and it

[2] Min. Res. U. S., 1893 (Rep. U. S. Geol. Survey), pp. 15 and 19.
[3] Min. Res. U. S., 1897 (Rep. U. S. Geol. Survey), p. 13.
[4] Am. Jour. Sci., IV, Vol. V, 1898, pp. 293-296; and also Vol. VI, pp. 463-468.

possesses a remarkable degree of brilliancy, especially in artificial light. Those qualities give it great value for gem purposes, and it has become very popular. The pieces found are not generally large, but stones have been cut of as much as 14 carats. A very fine exhibit of rhodolites was made in the State Geological Survey Exhibit at the recent Expositions at Buffalo, Charleston, and St. Louis. They have been developed by two companies with remarkable success; and apparently more gems in value have been sold from this mine than from all other sources in the State combined. (See Pl. XIII.)

Perhaps $53,000 worth of these stones have been sold from these mines to date.

ZIRCON.

Zircon (silicate of zirconia) is a mineral of somewhat wide distribution, though rarely conspicuous. It crystallizes in square prisms with pyramidal terminations, generally opaque and of some shade of brown. When transparent, and of any size, beautiful gems can be cut from zircon crystals; these are the hyacinths of jewelers.

In North Carolina zircon is abundant in the gold sands of Polk, Burke, McDowell, Rutherford, and Caldwell counties, and in nearly all the colors found in Ceylon—yellowish-brown, brownish-white, amethystine, pink, and blue. The crystals are beautifully modified, but too minute to be of value. Brown and brownish-yellow crystals, very perfect in form, occur abundantly in Henderson County, N. C., and in equal abundance in Anderson County, S. C. The latter are readily distinguished from the North Carolina crystals, as they are generally larger, often an inch across, and the prism is almost always very small, the crystal frequently being made up of the two pyramids only. They are found in large quantities, loose in the soil, as the result of the decomposition of a feldspathic rock. Large and richly colored zircons, sometimes as much as 2 ounces in weight, and of fine shades of brown and honey-red, are found in Iredell County.[5].

Within the past 20 years some demand has arisen and continued for minerals containing the rare earths,—zirconia, thoria, etc.,—as these substances are used for the mantles or hoods of the Welsbach and other forms of incandescent gas burners. This demand led to active search throughout the world for the minerals containing these oxides, and so successful has been this search that many species which were once considered rare are now so plentiful that they are quoted at one-tenth to one-

[5] N. C. Geolog. Survey, Economic Paper, No. 6, 1901, p. 99; and Department of Mining Statistics, 1898, p. 34.

hundredth of their former prices. The best zircon localities in North Carolina are on the Old Meredith Freeman estate, and the Jones estate, Green River, Henderson County. It was leased for 25 years by Gen. Thomas L. Clingman, who, as early as 1869, mined 1000 pounds of zircon, and during that whole period never lost faith in the incandescent properties of zirconia; but when these were finally proved and acknowledged, through some legal difficulties General Clingman had forfeited his leases, and hence failed to reap his reward. The zircon industry has been quite important in North Carolina; and as far back as 1883 Mr. W. E. Hidden mined 26 tons in that single year. The chemical composition of zircon is shown below in the analysis of a sample of this mineral from Buncombe County.

Analysis[6] *of Zircon from Buncombe County, N. C.*

Specific Gravity, 4.607.

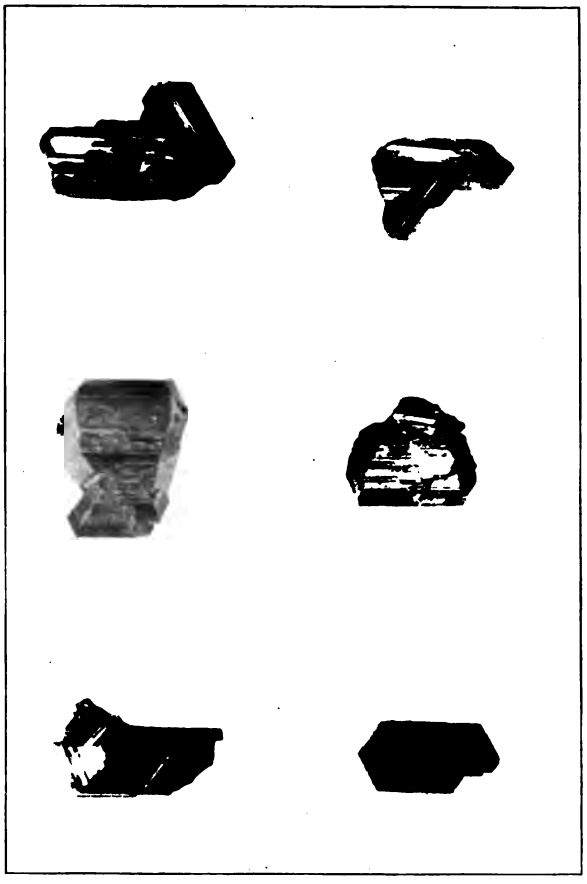
Constituent.	Per cent.	Theoretical per cent.
Silica	33.70	32.80
Zirconia	65.30	67.20
Ferric Oxide	0.67	.....
Water	0.41	.....

RUTILE.

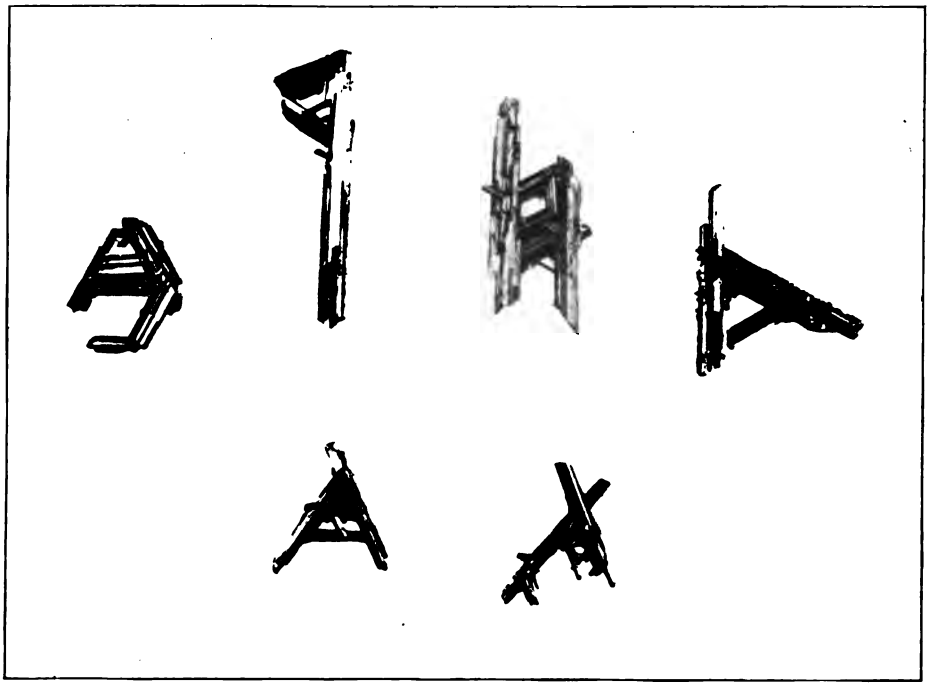
This is one of the most interesting minerals found in North Carolina, although not one that is very conspicuous. In composition, it is pure oxide of the metal titanium, and varies in color from deep red or reddish-brown to black, the crystals being modified square prisms. Specimens from Alexander County rival any that have ever been found for their perfection of form, wonderful polish, and fine color (Pl. XIV, A and B, and Pl. XV). At Graves Mountain, Georgia, elegant rutile occurs with lazulite usually imbedded in a compact red oxide of iron that can be readily removed by hydrochloric acid, or with a sharp instrument, leaving on the surfaces a mirror-like polish. The crystals vary in length from ½ an inch up to 5 inches, and are either single, twins, or vierlings, often in fine groups. The rutile from this locality has realized at least $20,000 for cabinet specimens, and has supplied the collections of the world through the perseverance of Prof. Charles U. Shepard. It occurs in a similar association with lazulite in North Carolina, at Crowders Mountain, in Gaston County.

The finest small brilliant geniculated crystals are found at Millholland's Mills, White Plains, near Liberty Church, and near Poplar Springs, in

[6] C. F. Chandler, analyst, Am. Jour. Sci., II, 24, 131.



A. RUTILE CRYSTALS, NATURAL SIZE, STONY POINT, N. C.



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Alexander County, see Plate XIV. These have furnished some of the finest cut black rutile, which more closely approaches the black diamond in appearance than any other gem. Some of the lighter colored ones furnish gems strongly resembling common garnet. Beautiful long crystals at times transparent red, ranging from the thickness of a hair to $\frac{1}{4}$ and in some instances $\frac{2}{3}$ inch across, and from 1 inch to 6 inches in length, often doubly terminated and very brilliant, have been found at Taylorsville, Stony Point, and elsewhere in that vicinity. A very marked form of rutile is that in which these slender red crystals penetrate transparent quartz, both colorless and smoky, forming the beautiful combination called sagenite, or by the French, "fléches d'amour" (love's arrows) (Pl. V). This material is found of remarkably fine quality at several points in North Carolina, and is described in this report under Quartz Inclusions.

Dr. Joseph Hyde Pratt has recently reported the occurrence of beautifully terminated rutile crystals from near Mebane, Orange County. The crystals are up to $1\frac{1}{4}$ inches long and $\frac{1}{2}$ broad and are imbedded in pyrophyllite.

OCTAHEDRITE.

Octahedrite is a rare mineral, identical with rutile in composition, but entirely different in the form of its crystals. It is described by W. E. Hidden [7] as occurring in thin tabular, glassy crystals of a pale-green color and very brilliant up to $\frac{1}{3}$ of an inch in diameter, in the gold sands of Brindletown Creek and elsewhere in Burke and the adjoining counties, especially on the northern slope of Pilot Mountain. These might afford small gems that would compare favorably with the beautiful blue crystals from Brazil, which are so brilliant as to have been mistaken for diamonds. Cassiterite, the oxide of tin, has been found in considerable quantities at King's Mountain. Fine specimens may be cut like rutile, but this place has not yielded a single gem, or been worked as yet with commercial success for tin.

[7] Am. Jour. Sci., III, Vol. XXII, July, 1881, p. 26.

CHAPTER VIII.

CYANITE, EPIDOTE, TOURMALINE, CHRYSOLITE (PERIDOT), SERPENTINE, SMARAGDITE, LAZULITE, MALACHITE, AND PEARLS.

CYANITE.

This mineral (also spelled kyanite) is a subsilicate of alumina almost identical in composition with andalusite, and very closely related also to topaz. It is named from the Greek *kuanos,* blue, in allusion to its prevailing color, and was also called by old writers *sappar,* from a corruption of sapphire, which the fine clear cyanites of deep tint sometimes resemble. It occurs generally in long prismatic or blade-like crystals, and is not uncommon in the gneissic rocks of New England and Southeastern Pennsylvania to North Carolina (Pls. XIII and XII, B). It presents various shades of blue and blue-green, occasionally varying to pure white, —the variety from the Tyrol called rhœtizite. Fine crystals occur with lazulite at Clubb's and Crowder's mountains, on the road to Cooper's Gap, in Gaston County, and also in Rutherford County. Cyanite is somewhat frequently associated with corundum, from which Dr. Genth believed it to be derived by alteration. Another locality is at Swannanoa Gap, in Buncombe County; but the finest specimens are found in Mitchell County,[1] where it occurs in distinct isolated crystals that, for perfection, depth of color, and transparency, rival those from St. Gothard, Switzerland. The locality is at an altitude of 5500 feet, near the summit of Yellow Mountain on the road to Marion, 4 miles southeast of Bakersville, in a vein of white massive quartz in a granitic bluff, associated with almandite garnet of a very light transparent pinkish-purple color. The vein has a dip of 60 degrees, bearing northeast and southwest. The color varies from almost colorless to deep azure-blue, as dark as the Ceylonese sapphire, also occasionally green. Some of the crystals are 2 inches long, while a few were observed $\frac{3}{8}$ inch (15 millimeters) in width and $\frac{2}{5}$ inch (10 millimeters) in thickness. Occurring in white quartz, they form beautiful specimens, and the loose crystals were extensively sold for sapphire some years ago, at Roan Mountain, the summer resort. A few

[1] Am. Jour. Sci., III. Vol. XXXVI. p. 224. Sept., 1888.

gems have been cut, and a fine example is in the United States National Museum. It is, however, too soft to admit of much wear.

Another locality of fine cyanite in the same vicinity, was described in 1898 by Dr. J. H. Pratt.[2] This was on the farm of Mr. T. Young, in Yancey County, on North Toe River, a few miles from Spruce Pine, Mitchell County. Here the cyanite is frequently of a rich mossy green color, sometimes perfectly transparent; and some of the crystals are blue along the center with grass-green margins. Many of them are terminated, which is not common in cyanite; and the locality seems a very promising one.

EPIDOTE.

Prof. Frederick A. Genth mentions[3] a crystal of epidote in the cabinet of the University of Pennsylvania, from the gold-washings of Rutherford County, N. C. This crystal is strongly pleochroic, like the so-called puschkinite from the auriferous sands of Ekaterinburg, in the Ural Mountains, and would cut into a small gem. Some fine highly complex forms have been observed at Hampton's, Yancey County, by William E. Hidden. These crystals might possibly afford cabinet gems, not equal, however, to the Tyrolese epidote. Handsome prismatic crystals, 1½ inches in length and ⅓ in diameter, have been reported by Mr. O. H. Blocher, of Old Fort, McDowell County, as found some 40 miles from that place, but with no more specific location. They are brilliant, but of too dark a green to have much promise as gems.

Crocidolite was observed by Joseph Wilcox in long, delicate fibers of a blue color, in one of the western counties of North Carolina.

TOURMALINE.

This is a complex boro-silicate of alumina and several oxides, which is frequent in various crystalline rocks, and in its common black form is found at numerous North Carolina localities. But the richly colored varieties which are valued as gem stones, and are found in Maine, Connecticut, and Southern California, do not appear in North Carolina. The only announcement of the presence of any of them, thus far, was made several years ago by Messrs. D. C. Morgan and Company, of Waynesville, Haywood County, who reported crystals of transparent green tourmaline as found near that place. The colored tourmalines usually contain some lithia, and are nearly always found, when they do occur, in pegmatite dikes. As these latter are frequent in the western counties,

[2] Am. Jour. Sci., IV, Feb., 1898, pp. 126, 127.
[3] Minerals and Mineral Localities of North Carolina, Raleigh, p. 44, 1881.

it seems remarkable that almost no tourmalines of this kind have been found in all the mining and prospecting work.

CHRYSOLITE (OLIVINE, PERIDOT).

This mineral is a silicate of magnesia and iron. It occurs largely in an altered form in North Carolina, as the leading constituent of the decomposed peridotites called dunites, but very rarely in its unchanged condition. It is a green to yellow mineral, nearly as hard as quartz (6.5-7), and when transparent and in pieces of any size, it is valued as a brilliant gem-stone,—the chrysolite or peridot of jewelers. Near Webster, in Jackson County, it is found in granular masses, of a bright yellow-green color, and susceptible of a fine high polish. This material, if present in any quantity, might be utilized as a pleasing ornamental stone; but not as a gem, unless more transparent and in larger pieces.

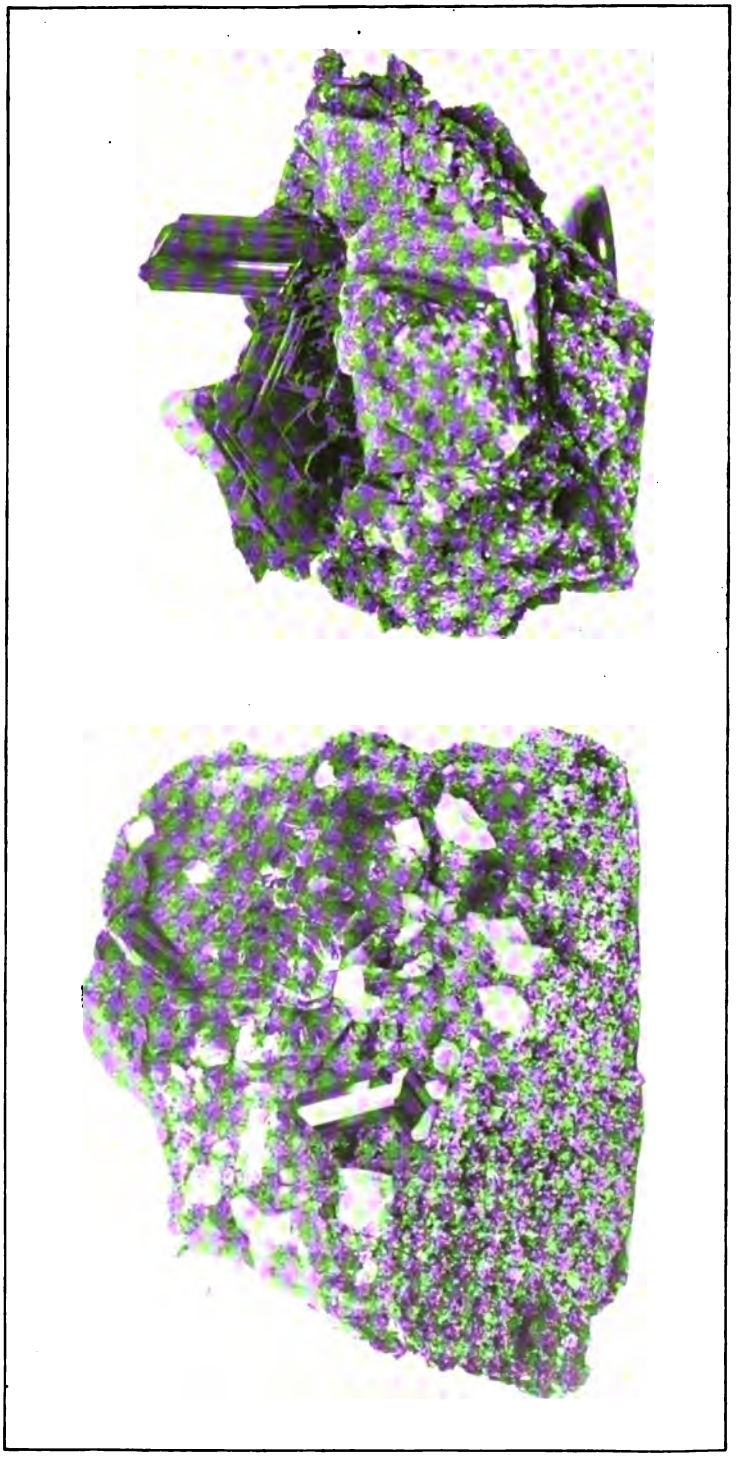
Analyses of Chrysolite from Webster, Jackson County, N. C.

Constituent.	Per cent.[4]	Per cent.[5]	Per cent.[6]
Silica	41.89	40.74	41.17
Ferric Oxide / Chromic Oxide	0.58	1.83	.....
Ferrous Oxide	7.39	7.26	7.35
Nickel Oxide	0.35	0.39	0.41
Lime	0.06	0.02	0.04
Magnesia	49.13	49.18	49.16

[4] F. A. Genth, analyst, Am. Jour. Sci., III, 33, 200.
[5] l. c.
[6] F. A. Genth, analyst, Am. Jour. Sci., II, 33, 199.
[4] Color, pale grayish green.
[5] and [6] Color, yellowish olive green.

SERPENTINE.

This mineral, a hydrous silicate of magnesia, occurs widely distributed throughout some portions of the State, and is often a result of the alteration of the olivine-bearing rocks (peridotite, dunite) already repeatedly mentioned. At some points it is massive and of good color and quality, such as might be used for building-stone, as it is frequently near Philadelphia. But the translucent and rich green variety known as precious serpentine, which is used as an ornamental stone like that of Maryland, has been recognized only at a few points and does not appear as yet to have been utilized at all. Dr. Pratt mentions several promising outcrops in Buncombe County, between Leicester and Weaversville, and others in Madison and Yancey counties. Still another, where the serpentine is of fine quality, is in Wilkes County, where it forms the rock of the asbestos



A. RUTILE, WITH DOLOMITE AND MUSCOVITE. B. RUTILE GROUP, NATURAL SIZE, STONY POINT, N. C.

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mine near North Wilkesboro. It is hard and compact and polishes handsomely, and might prove as beautiful as that of Harford County, Maryland. Dr. Genth, also, years ago, stated that a serpentine from the neighborhood of Patterson, Caldwell County, of a dark greenish-black color, admits of a fine polish.[7]

Analysis[8] *of Serpentine, Webster, N. C.*

Constituent.	Per cent.
Silica	43.87
Alumina	0.31
Ferrous Oxide	7.17
Nickel Oxide	0.27
Magnesia	38.62
Water	9.55

EDENITE (SMARAGDITE.)

Smaragdite is a variety of hornblende (amphibole), which occurs plentifully at the Cullakenee Corundum Mine, Clay County, N. C. In color it is bright emerald to grass-green, also grayish and greenish-gray. Masses through which the pink and ruby corundum occur disseminated, are exceedingly beautiful. The mineral is hard enough to admit of a fine polish and is worthy of attention as an ornamental or decorative stone. It has recently been utilized for such purposes, under the name of "ruby matrix." Pieces are selected in which bright portions of red or pink corundum are enclosed in the rich green smaragdite, and the contrast makes a very attractive material. Smaragdite occurs also near Elf, on Shooting Creek, in the same county, similarly associated with corundum, pink and dark blue.

LAZULITE.

Lazulite is a somewhat rare mineral, a phosphate of alumina containing some magnesia and protoxide of iron. It occurs in pale and dark blue crystals and crystalline masses at Clubb Mountain and Crowder's Mountain, in Gaston County, and at Sauratown, in Stokes County. The finest crystals, however, come from Graves' Mountain, Georgia, some of them being as much as two inches in length. Its hardness is 6, and its specific gravity is 3.122. This mineral would make an opaque gem or an ornamental stone, as the color, though lighter, is often as rich as that of lapis lazuli, for which it was mistaken when first found.

[7] Mineral of N. C., p. 57.
[8] F. A. Genth, analyst, Am. Jour. Sci., II, 33, 201.

Analysis[9] *of Blue Lazulite from Gaston County, N. C.*

Constituent.	Per cent.	Per cent.
Phosphoric Acid	43.38	44.15
Alumina	31.22	32.17
Ferrous Oxide	8.29	8.05
Magnesia	10.06	10.02
Silica	1.07	1.07
Water	5.68	5.50
Hardness	5.0-6.0	5.0-6.0

MALACHITE.

This beautiful green carbonate of copper, often used as an ornamental stone as well as mined for an ore of the metal, is found somewhat in Guilford, Cabarrus, and Mecklenburg counties. The fibrous variety has been observed at Silver Hill and at Conrad Hill, in Davidson County, and in a number of other localities in North Carolina, but is rarely of any gem value. In the Torrey Collection at the United States Assay Office, in New York City, are a few fine gem pieces of malachite from the Copper Knob mine in Ashe County.

PEARLS.

The Indians of Carolina, Georgia, Florida and Alabama, gathered mussels and conchs, as shown by the numerous refuse piles and shell heaps that abound upon the salt-water creeks. It is not a matter of surprise that the Indians, as they opened these shells, should have carefully watched for pearls, and from the vast numbers examined, should have accumulated a store. If the shores of Carolina, Georgia, and Florida did not afford the larger and more highly prized pearls, it is not impossible that pearls from the islands and lower portions of the Gulf of Mexico, and even from the Pacific coast, may have found their way into the heart of Georgia and Florida and into more northern localities, to be there bartered away for skins and other articles. The replies of Indians to Father Hennepin and others and the presence in remote localities of beads, ornaments, and drinking-cups made of marine shells and conchs, still peculiar to the Gulf of Mexico, confirm the truthfulness of this suggestion.[10]

[9] Analysts, Smith & Brush. Dana, Mineralogy, 5th ed., p. 572.

[10] Ancient Aboriginal Trade in North America, by Charles Rau. Report of the Smithsonian Institution for 1872, Washington, 1873; Gems and Precious Stones of North America, New York, 1890-92; U. S. Commission Fish and Fisheries, 1893-98; Pearls, by Geo. F. Kunz, Charles H. Stevenson, Century Co., New York, 1907.

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